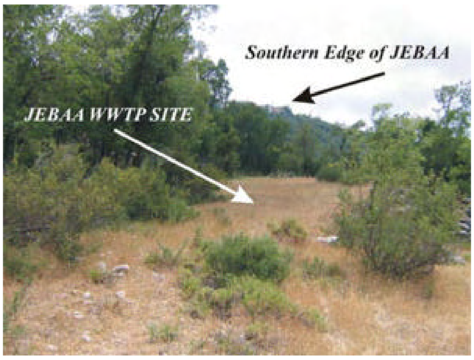
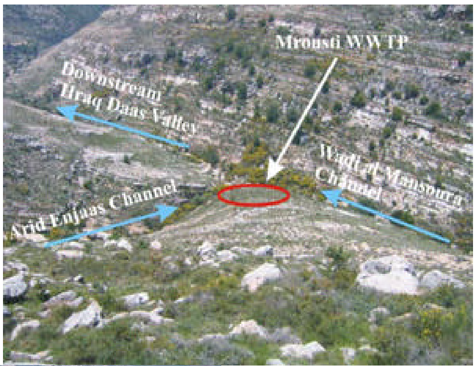
ENVIRONMENTAL IMPACT ASSESSMENT

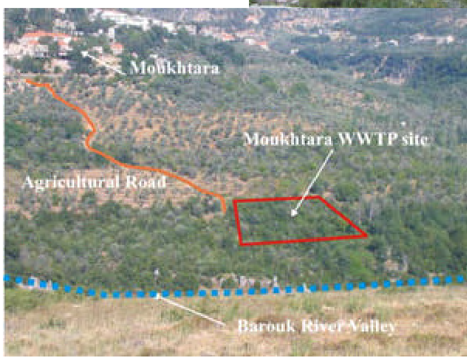
WASTEWATER TREATMENT PLANTS

HIGHER SHOUF MUNICIPALITIES

CAZA OF SHOUF







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Submitted to:
Catholic Near East Welfare Association
PONTIFICAL MISSION

September 2004

TABLE OF CONTENTS

TABLE OF CONTENTS .... **II**

LIST OF TABLES .... **VIII**

LIST OF FIGURES .... **XI**

LIST OF PHOTOGRAPHS .... **XII**

LIST OF ABBREVIATIONS .... **XIV**

NON-TECHNICAL SUMMARY .... **XVII**

INTRODUCTION XVII

LEGAL AND INSTITUTIONAL FRAMEWORKS XVII

PUBLIC INVOLVEMENT XVIII

DESCRIPTION OF THE PROJECT XVIII

DESCRIPTION OF THE ENVIRONMENT XX

IMPACT ASSESSMENT XXI

ENVIRONMENTAL MANAGEMENT PLAN XXI

1. INTRODUCTION **1**

1.1. THE OVERALL CONTEXT 1

1.2. BACKGROUND AND RATIONALE 1

1.3. THE PROJECT 5

1.4. THE PROJECTS LOCATION 6

1.5. THE STUDY AND THE EIA REPORT 7

2. LEGISLATIVE AND INSTITUTIONAL FRAMEWORKS **9**

2.1. LEGISLATIVE FRAMEWORK 9

2.2. INSTITUTIONAL FRAMEWORK 13

3. BACKGROUND INFORMATION **14**

3.1. PROJECTS INITIATION 14

3.2. IMPORTANCE OF THE PROJECT 14

3.3. OBJECTIVES OF THE PROJECT 16

3.4. THE EXECUTING OFFICE 16

4. DESCRIPTION OF THE PROJECT 17

4.1. GENERAL DESCRIPTION OF THE PLANT 17

4.2. PROCESS THEORY 19

4.2.1 Anaerobic Biological Treatment Processes 21

4.2.1.1 Anaerobic Reactor Types 22
4.2.1.2 High Rate Suspended Growth Anaerobic Reactors 23

4.2.2 Aerobic Biological Treatment Processes 25

4.2.2.1 Aerobic Reactor Types 26
4.2.2.2 Activated Sludge (Suspended Growth) Aerobic Reactors 28
4.2.2.3 Trickling Filter (Attached Growth) Aerobic Reactor 29

4.3. ANALYSIS OF ALTERNATIVES 32

4.3.1 Process and Technology Selection 32

4.3.2 Site Selection 38

4.3.2.1 Site Selection in Jebaa 39

4.3.3 Site Selection in Mrousti 42

4.3.4 Site Selection in Moukhtara 44

4.4. DETAILED PROCESS DESCRIPTION 48

4.5. EFFLUENTS CHARACTERIZATION AND MANAGEMENT 52

4.5.1 Liquid Effluent 52

4.5.1.1 Liquid Effluent Characteristics 52
4.5.1.2 Liquid Effluent Management 52

4.5.2 Sludge Effluent 53

4.5.2.1 Sludge Characteristics 53
4.5.2.2 Sludge Management 55

4.5.3 Miscellaneous Wastes 56

4.6. PLANT CONSTRUCTION 56

5. DESCRIPTION OF THE ENVIRONMENT 58

5.1. GENERAL SETTING 58

5.2. METEOROLOGICAL SETTING 59

5.2.1 Precipitation 60

5.2.2 Temperatures 62

5.2.3 Winds ... *62*

5.3. SITE SETTING ... 63

5.3.1 Jebaa WWTP Site ... *63*

5.3.2 Mrousti WWTP Site ... *65*

5.3.3 Moukhtara – Butmeh WWTP Site ... *66*

5.4. GEOLOGICAL SETTING OVER JEBAA & MROUSTI ... 68

5.4.1 Stratigraphy ... *68*

5.4.1.1 Jurassic ... 69
5.4.1.2 Cretaceous ... 69

5.4.2 Structure ... *71*

5.4.3 Hydrogeological Setting ... *73*

5.4.3.1 Aquifers ... 73
5.4.3.2 Aquicludes (Abeih and Hammana aquicludes; C_3 -C_{2b} Formation) ... 75
5.4.3.3 Spring Survey ... 75

5.4.4 Hydrogeological Site Setting (Jebaa / Mrousti) ... *78*

5.5. GEOLOGICAL SETTING OVER MOUKHTARA & BUTMEH ... 78

5.5.1 Stratigraphy ... *79*

5.5.1.1 Cretaceous ... 79

5.5.2 Structure ... *80*

5.5.3 Hydrogeological Setting ... *80*

5.5.3.1 Aquifers and Aquicludes ... 80
5.5.3.2 Spring Survey ... 80

5.5.4 Hydrogeological Site Setting (Moukhtara Site) ... *81*

5.5.5 Hydrological Setting of the Study Area ... *82*

5.5.5.1 The Barouk River ... 82

5.6. WATER QUALITY ... 83

5.6.1 Spring Analysis ... *83*

5.6.2 Barouk River Analysis ... *85*

5.7. ECOLOGICAL CONTEXT (BIODIVERSITY) ... 86

5.7.1 Ecological Context in Mrousti ... *86*

5.7.2 Ecological Context in Jebaa ... *90*

5.7.3 Ecological Context in Moukhtara Site ... *91*

5.8. INFRASTRUCTURE STATUS 92
5.9. SOCIO-ECONOMIC STATUS 93
6. IMPACT IDENTIFICATION AND ANALYSIS 95
6.1. IMPACTS ON WATER RESOURCES 95
6.1.1 Impacts during Construction 95
6.1.2 Impacts during Operation 97
6.2. IMPACTS ON SOIL 98
6.2.1 Impacts during Construction 98
6.2.2 Impacts during Operation 98
6.3. IMPACTS ON HUMAN AMENITY 99
6.3.1 Impacts during Construction 99
6.3.2 Impacts during Operation 99
6.4. IMPACTS ON PUBLIC AND OCCUPATIONAL SAFETY 100
6.4.1 Impacts during Construction 100
6.4.2 Impacts during Operation 100
6.5. IMPACTS ON BIODIVERSITY 100
6.5.1 Impacts during Construction 100
6.5.2 Impacts during Operation 101
6.6. IMPACTS ON HUMAN HEALTH AND SANITATION 101
6.7. SOCIOECONOMIC IMPACTS 102
6.8. IMPACTS ON ARCHAEOLOGICAL, TOURISTIC AND CULTURAL SITES 102
7. ENVIROMENTAL MANAGEMENT PLAN 103
7.1. OBJECTIVES OF THE ENVIRONMENTAL MANAGEMENT PLAN 103
7.2. MITIGATION MEASURES 103
7.2.1 Defining Mitigation 103
7.2.2 Mitigating Adverse Project Impacts 103
7.2.3 Mitigating Degradation of Receiving Water Quality 104

7.2.4 Mitigating Dust Emissions ... 105

7.2.5 Mitigating Noise Pollution ... 105

7.2.6 Mitigating Obnoxious Odors ... 106

7.2.7 Mitigating Aerosol Emissions ... 107

7.2.8 Mitigating Impact on Biodiversity ... 108

7.2.9 Mitigating Impacts from Residual Storage, Handling, Transport, and Reuse/Disposal ... 109

7.2.10 Mitigating Adverse Aesthetic Impacts ... 111

7.2.11 Mitigating Public and Occupational Health Hazards ... 112

7.3. ENVIRONMENTAL MONITORING PLAN ... 116

7.3.1 Compliance Monitoring ... 116

7.3.2 Impact Detection Monitoring ... 122

7.4. COST OF MONITORING ... 123

7.5. RECORD KEEPING AND REPORTING ... 125

7.6. CONTINGENCY PLAN ... 125

7.7. CAPACITY BUILDING ... 126

7.7.1 Operators Training ... 126

7.7.2 Specialized Training Workshops (STW) ... 126

7.7.3 General Awareness Seminars (GAS) ... 126

7.8. INSTITUTIONAL ARRANGEMENTS ... 127

8. PUBLIC INVOLVEMENT AND PARTICIPATION ... 128

9. REFERENCES ... 130

APPENDIX A TECTONIC MAP OF LEBANON; GEOLOGICAL MAP OF STUDY AREAS (JEBAA/MROUSTI & MOUKHTARA/BUTMEH); CROSS SECTIONS ... 132

APPENDIX B TOPOGRAPHIC MAPS INDICATING SAMPLING LOCATIONS; LABORATORY ANALYTICAL RESULTS – SPRINGS WATER – BAROUK RIVER. ... 133

APPENDIX C ARCHITECTURAL DRAWING OF AN EAAS PLANT TO BE IMPLEMENTED IN THE VILLAGES. ... 134

APPENDIX D SURVEYED SITES LOCATION. 135

APPENDIX E SLUDGE AND EFFLUENT MANAGEMENT.... 136

APPENDIX F WASTEWATER TREATMENT AND USE IN AGRICULTURE - FAO IRRIGATION AND DRAINAGE PAPER 47. (SECTION 5) 151

APPENDIX G INCEPTION WORKSHOP \ PUBLIC INVOLVEMENT, MINUTES OF MEETING \ QUESTIONNAIRES 190

APPENDIX H EMP COMPLIANCE FORMS AND OFFICIAL PUBLIC NOTICES 199

APPENDIX I COST OF ENVIRONMENTAL MONITORING PROGRAM 200

APPENDIX J SAMPLE TENDER DOCUMENTS FOR A WWTP 203

LIST OF TABLES

TABLE PAGE

1.1. Projected Populations, Property Location, and Available Acreage 7

2.1. Categories of Legislation in Lebanon..10

2.2. Summary of Selected Legislation Related to Wastewater Management 11

2.3. Law 444 and Draft EIA Decree 12

2.4. Selected Standards for Discharge into Surface Waters...12

2.5. Responsibilities and Authorities of Key Institutions in Lebanon.......................................13

4.1. Present and Projected Populations for the village Being Served by Treatment Plant 18

4.2. Contribution from the village to the total inflow of raw sewage to the treatment plant 18

4.3. Characterization of Raw Wastewater..18

4.4. Description of Wastewater Treatment Stages...20

4.5. Inhibition Concentrations of Various Ions...22

4.6. Summary of Anaerobic Reactor Types..23

4.7. Comparison of Aerobic Suspended Growth and Attached Growth Reactors.....................27

4.8. Comparison of the Waste Products of Aerobic Reactors..28

4.9. Advantages and Disadvantages of Trickling Filters 31

4.10. Properties of Trickling Filter Media 31

4.11. Nitrification Ability of Various Trickling Filter Media Nitrification...............................32

4.12. Analysis of Different Scenarios/alternatives of Wastewater Treatment Schemes............34

4.13. Advantages of EAAS over Conventional Activated Sludge Treatment 36

4.14. Analysis of Process Selection Alternatives...37

4.15. Summary of Site Selection Process in Jebaa 41

4.16. Summary of Site Selection Process in Mrousti...43

4.17. Analysis of scenarios for the location and number of wastewater treatment plants for Butmeh and Moukhtara. 46

4.18. Treatments levels achievable with various combinations of unit operations and processes used for advanced wastewater treatment. 50

4.19. Average Daily Volumes of Treated Liquid Effluents..52

4.20 Typical Ranges for Chemical Composition of Activated Sludge 54

4.21. Typical Metal Content in Wastewater Sludge 54

4.22. Selection of best management practice for generated WWTPs sludge 56

5.1. Characteristics of surveyed springs 78

5.2. Characteristics of surveyed springs 81

5.3. Laboratory Analytical Results of Five springs in Higher Shouf Municipalities Union (Samples Collected on 09/09/2003) 84

5.4. Analytical results of collected effluent from Baadaran treatment plant 85

5.5. Laboratory Analytical Results of three samples collected from random locations over the Barouk River 86

5.6. Chemical grading for Rivers and Canals. (Thames river-Standards 2000) 86

5.7. Socio-Economic Information (as given by Municipalities and Union) 94

6.1. Impact Identification Matrix...96

6.2. Potential Negative Impacts on Biodiversity...101

7.1. Suggested minimum buffer distances from treatment units 106

7.2. Additional Mitigation of Impacts on Biodiversity Specific to the Location....................108

7.3. Mitigation Measures, Monitoring, and Estimated Costs for Actions Affecting Environmental Resources and Human Amenity 113

7.4. Process control parameters for an EAAS system 118

7.5. Process performance parameters for an EAAS system....119

7.6. Process performance parameters suggested in a draft law set by the MoE. 120

7.7. Sludge quality monitoring parameters 122

7.8. Monitoring Cost for Process Performance Parameters 124

LIST OF FIGURES

FIGURE **PAGE**

1.1. Constraints Hindering Infrastructure Development in Rural Communities in Lebanon......5

4.1. Schematic Diagram of a UASB Reactor..24

4.2. Schematic Diagram of an ACR..25

4.3. Comparison between Aerobic and Anaerobic Biological Treatment (Journey, W.K.) 26

4.4. Flow Diagram for the Complete-Mix Activated Sludge Process 29

4.5. Diagram of Trickling Filters 30

4.6. Flow Diagram of EAAS Treatment Plant with Advanced Treatment Units 51

5.1. Detailed topographic map showing the road network in the study area
(Scale: 1:200’000)..59

5.2. Pluviometric Map of the Higher Shouf Area and Surroundings (Scale 1: 200 000)
(Service Météorologique du Liban, 1977) 61

5.3. Precipitation Data from AUB (34 m), Jdeidet El Shouf (770 m) and Gharife (680 m)
Stations (Elevations are from mean sea level). 61

5.4. Average Monthly Temperature Data from AUB (34 m), Kfar Nabrakh (1020 m) and
Gharife (680 m) Stations (Elevations are from mean sea level). 63

5.5. Hydrograph of Barouk Spring (1945 –1969)...82

5.6. Hydrograph (1929-1955) of the Awali River on the Marj Bisri Station (UNDP, 1970) 83

7.1. Proposed Institutional Setting...127

LIST OF PHOTOGRAPHS

PHOTOGRAPH **PAGE**

3.1. Discharge of Wastewater in winter channels downstream to Mrousti village 16

5.1. General view the proposed site for the wastewater treatment plant, in Jebaa site located towards the Western outskirts of the village. Photograph looking towards the South direction. 64

5.2. Band of Quercus sp. trees surrounding the site 65

5.3. General view the proposed site for the wastewater treatment plant in Mrousti located towards the Western outskirts of the village. Photograph was taken from a cliff overlooking the site. 66

5.4. Approximate road and main sewage network location to reach the WWTP site. Photograph looking towards the East direction. 66

5.5. General view the proposed site for the wastewater treatment plant in Moukhtara located towards the Western outskirts of the village. Photograph was taken from the side of Kahlouniyeh facing Moukhtara, looking towards the East. 67

5.6. General setting around the Moukhtara village. Photograph taken from Kahlouniyeh village looking towards the East. 68

5.7. Photograph taken in Jebaa showing the Sannine Formation characterized by oysters' fossilized shells 70

5.8: Photograph showing the succession of formations South-East from the wastewater plant site location 71

5.9. Fault passing through Qalaa El Kaouayer in Mrousti. Note the displacements occurring in the cliffs belonging to the Sannine Formation. 72

5.10. Photograph showing the trace of a fault passing north to Jebaa Village facing the location of the wastewater plant, note the variation of dip near the fault trace 73

5.11. Ain Abdallah spring, a Seepage zone along the main road in Mrousti.............................76

3.12. Ain El Ghebe on the road leading from Mrousti to Khraibeh 76

3.13. Ain Jebaa ech Chouf spring in Jebaa next to the municipality 77

3.14. Ain Mrousti in the Village 77

3.15. Ain Mouchqir in Khraibeh, located on the boundary between Sannine and Hammana formation 81

3.16. Sampling at Ain-Mourchid location 84

3.17. Sarcopoterium spinosum and Centaurea calcitrapa 87

3.18. Spartium junceum with its typical bright yellow flowers 87

3.19. Calycotome villosa 88

3.20. Identified flora in Mrousti site 89

3.21. Quercus sp. community and shrubs surrounding the site. Photograph taken within the site 90

3.22. Spartium spp, Quercus spp. community around the site 91

3.23. Regenerating Quercus sp. community and olive orchards in the proposed site 91

3.24. Olive tree competing with the regenerating native shrubs and trees 92

LIST OF ABBREVIATIONS

ELARD	Earth Link and Advanced Resources Development
As	Arsenic
AUB	American University of Beirut
BIA	Beirut International Airport
BOD_5	5-day Biochemical Oxygen Demand
BMLWWE	Beirut and Mount Lebanon Water and Wastewater Establishment
C	Composite Sample
C_3	Hammana Formation
C_{2b}	Mdairej Formation
C_4	Sannine Formation
Cd	Cadmium
CDR	Council for Development and Reconstruction
CNEWA\PM	Catholic Near East Welfare Association \ Pontifical Mission
Co	Cobalt
COD	Chemical Oxygen Demand
Cr	Chromium
Cu	Copper
DMR	Discharge Monitoring Report
E	East
EAAS	Extended Aeration Activated Sludge
EIA	Environmental Impact Assessment
ELV	Environmental Limit Values
EMP	Environmental Management Plan
ES	Environmental Statement
Fe	Iron
G	Grab Sample
GAS	General Awareness Seminar
GBA	Greater Beirut Area
GDP	Gross Domestic Product
Hg	Mercury
HL	Hydraulic Loading
ISWMP	Integrated Solid Waste Management Plan
M	Monthly
METAP	Mediterranean Technical Assistance Program

MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
Mn	Manganese
Mo	Molybdenum
MoA	Ministry of Agriculture
MoE	Ministry of Environment
MoIM	Ministry of Interior and Municipalities
MoI	Ministry of Industry
MoPH	Ministry of Public Health
MoPWT	Ministry of Public Works and Transport
MSW	Municipal Solid Waste
NGO	Non-Governmental Organization
NWMP	National Wastewater Management Plan
NH_3	Ammonia
Ni	Nickel
NNE	North Northeast
ON	Organic Nitrogen
Pb	Lead
PC	Process Control
PCB	Polychlorinated Biphenyls
PP	Process Performance
Se	Selenium
Sn	Tin
SWTP	Solid Waste Treatment Plant
SOP	Standard Operating Protocol
SPASI	Strengthening the Permitting and Auditing System for Industries
SRI	Stanford Research Institute
SRT	Solids Retention Time
SSW	South Southwest
STW	Specialized Training Workshop
SWEMP	Solid Waste Environmental Management Plan
TSS	Total Suspended Solids
UNDP	United Nations Development Program
UPP	Unit of Planning and Programming
VSS	Volatile Suspended Solids
W	West

WB	World Bank
WWTP	Waste Water Treatment Plant
Zn	Zinc
1/W	Once per Week
1/2W	Once per Two Weeks

^{0} C	Degrees centigrade
cm	Centimeter
hr	Hour
km	Kilometer
m	Meter
m^3	Cubic meters
m^3/day	Cubic meters per day
m^3/s	Cubic meter per second
mg/L	Milligrams per liter
mL	Milliliter
mm/year	millimeters per year
ppm	Parts per million

NON-TECHNICAL SUMMARY

INTRODUCTION

This Environmental Impact Assessment (EIA) has been prepared to address the potential environmental impacts that could arise from the construction and operation of domestic wastewater treatment plants in the Higher Shouf area. The intended plants will be located in the villages of Mrousti, Jebaa El Shouf, and Moukhtara, planned to serve the inhabitants of these villages in the higher Shouf area, Shouf Caza, Lebanon, along with the village of Butmeh, since the intended plant in Moukhtara will serve the inhabitants of the neighboring Butmeh village. Additionally, the EIA evaluates various alternative treatment technologies and presents technical criteria on which to base the selection of the most suitable technology.

The purpose of the project is to alleviate the severe impacts of uncontrolled sewage discharges into the environment. Proper design/selection, construction, and management of the wastewater treatment plants (and upgrading/construction of wastewater collection networks) would mitigate such negative impacts. The main sections of the EIA include *definition of the legal and institutional frameworks, description of the project and the environment, impacts assessment, identification of mitigation measures, and presentation of an environmental management plan (EMP).*

LEGAL AND INSTITUTIONAL FRAMEWORKS

In the legal framework, the draft EIA decree has been revised by the Unit of Planning and Programming (UPP) at the Ministry of Environment (MoE), and is waiting for legislative approval. This draft decree sets the procedures and guidelines for the proponent of every proposed project that could have significant impacts on the environment, to prepare its own EIA or Environmental Statement (ES). The MoE is the main institution responsible for the revision and approval of the EIA.

Institutionally, the Union of Municipalities of Higher Shouf deals mainly with the Ministry of Interior and Municipalities (MoIM) and the MoE, in addition to the Pontifical Mission.

PUBLIC INVOLVEMENT

The project is the foremost issue being requested from the municipalities in the Higher Shouf area. During this study, the consultant and CNEWA/PM working hand in hand met numerous times with the Head of the Union, with the representatives of each municipality and with technology providers. CNEWA/PM organized on Friday 5 September 2003, a first official project initiation meeting in the presence of his Excellency the ambassador of the United States of America, the Shouf area deputy (Mr. Walid Joumblatt) and USAID/Lebanon directors. During that meeting, the forecasted projects for the area were presented to the public. On October 18, 2003, an inception workshop was conducted in the presence of various relevant ministries, NGOs and various stakeholders. Many other meetings, presentation, and workshops relevant for each specific project are yet to be implemented as well. Relevant information was solicited using questionnaires distributed over the various municipalities. In compliance with EIA guidelines, a notice was posted at each concerned Municipality offices within the Union informing the public of the EIA study, the proposed wastewater treatment plant, and soliciting comments.

DESCRIPTION OF THE PROJECT

Currently, untreated sewage generated within the villages of Mrousti, Jebaa El Shouf, Moukhtara, and Butmeh, is directly being disposed off in the environment. This situation is exposing the public to the associated negative health impacts and is leading to deterioration of water quality in the area. Proper conveyance and treatment of sewage is of utmost importance to avoid such impacts, and will be addressed by the construction of wastewater treatment plant (and collection networks) to serve this area.

It is essential to note that potable water is being contaminated by the ingress of wastewater into the potable water springs distributed down gradient to the study area, mainly the villages of Aammatour, Ain Qani, Moukhtara and others. Wastewater is being discharged directly into run-off ditches and storm water galleries as well as uncontrolled septic tanks.

The evaluated wastewater treatment plants for the Higher Shouf typically employ conventional or modified secondary biological wastewater treatment schemes. However, due to geological and hydro-geological considerations, advanced tertiary levels of treatment were imperative in some of the villages. The plants would serve in total a design population in these villages (Jebaa, Mrousti, Moukhtara, and Butmeh) of approximately 7236 and 7823 by the years 2014 and 2024, respectively.

In the context of analysis, the following six alternative wastewater treatment schemes were screened: (1) Preliminary treatment, (2) Primary treatment alone, (3) Secondary biological treatment through suspended growth process, (4) Secondary biological treatment through attached growth process, (5) Secondary biological treatment through suspended growth process + attached growth, and (6) Tertiary treatment through additional filtration and disinfection. The "Do Nothing" scenario is not considered a legitimate option, since wastewater is currently being discharged without treatment into the environment. With the protection of the environment being the main issue, the treatment system shall include at a minimum a secondary treatment. While alternative 5 was selected for the Moukhtara plant, given its proximity to the Barouk River that withstands the minimum flow required in decision 8/1/2001, alternative 6 was selected for the Jebaa and Mrousti WWTP.

After meeting stringent quality standards, treated liquid effluent will be discharged into the environment with minimal to no adverse impacts. The plants may thus discharge the treated effluents into tributaries that lead to the nearby Barouk River. The expected quality of the liquid effluents shall meet and/or even have better values than the standards of effluent discharge to surface water recently published by the Ministry of Environment (MoE) (Decision 8/1/2001). Table A presents the main relevant effluent standards. Moreover, because advanced levels of tertiary treatment are required in some specific cases the liquid effluent will definitely have lower values than the set standards.

Table A. Effluent Standards of Treated Wastewater*

PARAMETER	*EFFLUENT STANDARDS*
PH	6 – 9
BOD_5	25
COD	125
SUSPENDED SOLIDS	60
AMMONIA-NITROGEN AS N	10
NITRATE	90
TOTAL PHOSPHORUS	10

*All units in mg/L except for pH (unit less)

The proposed disposal route for the sludge would be co-composting of sludge with the organic fraction of the municipal solid waste in the intended solid waste treatment plant to be implemented under the same program to serve the area of Higher Shouf. The expected high quality compost produced can then be used as an organic fertilizer or soil cover in agricultural lands.

DESCRIPTION OF THE ENVIRONMENT

The study area is located on the western slopes of the southern section of Mount Lebanon, with land elevations ranging between less than 500 m and 1250 m above sea level. The villages are specifically located over a range of 800 to 1300 from mean sea level A generally good road network connects the villages within the Union. Yet, access roads to proposed wastewater treatment plant sites needs to be rehabilitated.

The total annual precipitation in the area is approximately 1,000 mm. Temperature ranges from a minimum of -10 ºC in winter to a maximum of 35 ºC. Dominant winds are southwesterly. Continental east and southeasterly winds are frequent.

One major perennial river, the “Barouk River” passes through the study area. The villages of Jebaa, Mrousti, Moukhtara, and Butmeh in the study area are considered a recharge zone for underground aquifer and springs as well as surface water shed area that contributes in the overall flow of the down stream Barouk River.

The geological formations outcropping within the surveyed area range in age from the lower Cretaceous to upper Cretaceous. There are mainly four formations outcropping in the study area: Abeih formation in the lower Cretaceous. Three formations belong to the Upper Cretaceous formations: Mdairej formation (C_{2b}), Hammana formation (C_3), Sannine formation (C_4)

Two main aquifers are identified in the surveyed area: the Mdairej karstic aquifer and the Sannine karstic aquifer.

Sewage network infrastructure within the villages has not been completed, yet the connection to the forecasted plant needs to be set. Developed infrastructure within the villages is mainly limited to road network, telephone, electricity, and water supply. A local solid waste management system does not exist yet; most Higher-Shouf villages rely on private solid waste management companies.

The main supply of potable water in the study area is provided from a public well located in the neighboring village of Mrousti this well supplies a majority of the villages down gradient to Mrousti with potable water. Sewage related contamination has been detected in sampled springs located within and down gradient to the study area.

Local inhabitants are mainly members of the active population (between 18 and 50 years old). The economy in most municipalities of the union of higher Shouf is driven by agriculture, trade and services and money sent by expatriates. Average household income within the Union amounts to less than six million Lebanese pounds annually.

IMPACT ASSESSMENT

The assessment of impacts indicated that negative impacts should not be significant as long as process performance is continuously controlled. No significant impacts on water resources, soil, air, and biodiversity are anticipated based on the expected quality of the effluents and the planned effluent management practices as well as the limited land area used.

The advanced treatment levels in the Jebaa and Mrousti plants will lead to improved removal of contaminants and excellent quality of the treated effluent, thus leading to minimal risks of pollution of groundwater and surface water. The Moukhtara plant will meet the necessary standards for discharge of the effluent in the perennial Barouk River. Significant impacts could nevertheless result from malfunction or during non-operation periods of the plants when an insufficient level of treatment would be reached. The EMP aims at minimizing the likelihood of such events and hence the significance of such impacts. Note that a proven technology was selected from the beginning (extended aeration) in order to minimize the chances of malfunction or non-operation of the plants.

On the other hand, positive impacts with respect to public nuisance and human health are a direct consequence and key goals of the project implementation.

ENVIRONMENTAL MANAGEMENT PLAN

In order to ensure the proper operation of each plant, an EMP must be implemented. The EMP defines proper mitigation measures (Table B), regular monitoring of effluent quality, proper staff training, and organized record keeping, in addition to a contingency and emergency response plan. Monitoring of individual processes within each plant is of equal importance to allow identification of probable causes in case of unlikely process deficiencies.

Table B. Summary of Main Mitigation Measures

Impact	*Mitigation Measures*
Dust Emissions	♦ Dust emissions from piles of soil or from any other material during earthwork, excavation, and transportation should be controlled by wetting surfaces, using temporary wind breaks, and covering truck loads ♦ Piles and heaps of soil should not be left over by contractors after construction is completed. Also excavated sites should be covered with suitable solid material and vegetation growth induced
Noise Generation	♦ Temporary noise pollution due to construction works should be controlled by proper maintenance of equipment and vehicles, and tuning of engines and mufflers. Construction works should be completed in as short a period as possible by assigning qualified engineers and foremen ♦ Noise pollution during operation would be generated by mechanical equipment, namely transfer pumps, air blowers, and sludge dewatering units. Noise problems should be reduced to normally acceptable levels by incorporating low-noise equipment in the design and/or locating such mechanical equipment in properly acoustically lined buildings or enclosures
Odor Generation	♦ Store produced residuals in closed containers and transport them in enclosed container trucks ♦ Keep always an optimum aeration rate at the aeration tanks ♦ If possible, proper landscape around the facility may serve as a natural windbreaker and minimize potential odor dispersions, if present
Soil and Water Pollution	♦ Properly dispose of effluents; monitoring of effluents quality is essential to avoid misuse of the latter; re-use of effluents (sludge or treated wastewater) shall be performed as per appendix E

After a successful plant start-up period, when a less thorough monitoring schedule can be implemented, monitoring efforts can be limited to regular checks (weekly or bi-weekly, as needed) of effluent quality for the following parameters:

- pH and temperature
- BOD_5 and COD
- Suspended solids
- Total Nitrogen

- Total Phosphorus
- Ammonia-nitrogen
- Nitrate–nitrogen
- Phosphate
- Coliform bacteria

A suggestion is the establishement of a common laboratory for all the villages of higher Shouf area under the supervision of the union, for sampling and analysis for the seven WWTPs to be constructed. This laboratory would serve in developing databases, managing records and thus ensure better compliance in monitoring. More capital cost is required for laboratory equipment, and later for the permanent staff and expenses. However, a suggested on-site monitoring center laboratory would increase the overall effectiveness and ensure autonomy, and thus reduce the overall costs of monitoring in the long-run. If it is decided to reuse the effluent, fecal coliforms and chlorine residual should also be checked regularly. On-site monitoring of temperature, pH, and flow measurements would be continuous. Sludge monitoring is essential prior to be set for co-composting. If a more detailed monitoring scheme is judged necessary by the regulatory authorities, then a sustainable financial mechanism must be put in place to secure the necessary funds.

Impact detection monitoring shall be performed as well. Therefore, the tests performed over the various springs, wells and rivers in this study, prior to the implementation of the various treatment plants, should be used as a basis in order to assess the expected positive effects or impacts of waste water management over the various receiving water bodies in the area subsequently over the environment. It is recommended to perform quarterly monitoring (every three months) of the following springs:

- Ain el Arish (Aammatour)
- Ain Mourchid (Moukhtara).
- Ain el Fokor (Aammatour).

- Ain El Machair

The following parameters should be monitored:

- Fecal coliforms
- BOD_5
- Residual chlorine

As for the responsibility of the different plants personnel, Table C describes the tasks and duties of the main staff that will be in charge of the proper operation of each plant.

Table C. Main Responsibilities of Plant's Personnel

Title	*Main Tasks*
Plant Manager (can be for more than one plant)	♦ Schedule sampling events and keep records of sampling results for compliance monitoring ♦ Prepare a report of plant's performance (accidents, compliance of effluent to standards, sludge quality, etc…) on a monthly basis during the first year, and bi-annually the following years ♦ Ascertain that mitigation measures are adhered to
Assistant plant manager	♦ Conduct sampling and follow-up with the off-site chemical laboratory for results ♦ Supervise the plant's performance on a daily basis
Mechanical Engineer (part-time)	♦ Ascertain the proper functioning of electro-mechanical equipment at the plant
Electrical Engineer (part-time)	♦ Ascertain the proper functioning of electro-mechanical equipment at the plant
Laborer	♦ Responsible for the day-to-day operation and maintenance of the plant; reports problems to management

Monitoring efforts would be in vain in the absence of an organized record keeping practice. It is the responsibility of the treatment plant management along with the respective municipalities to ensure the development of a database that includes a systematic tabulation of process indicators, performed computations, maintenance schedules and logbook, and process control and performance monitoring outcomes. Such a historical database benefits both the plant operator and design engineers in order to predict any adjustments needed to be performed ahead of time for example winter and summer adjustments for the variation in the hydraulic loading, temperature and even biological loadings. In addition, in accordance with the requirements of the regulatory authority, the treatment plant should submit a periodic Discharge Monitoring Report (DMR) to the assigned authority. The institutional setup for the project is proposed in Figure I.

The main supervising authority for the plants would be the Union. The Union along with CNEWA\PM and the selected contractor would supervise all the activities at the plants, starting from the design and construction phases, and continuing at the operation phase where it will be mandatory for the contractor to provide constant and regular technical checkups. The corresponding municipalities, however, would perform operation and day-to-day management. The MoE would have a regulatory role and the MoIM would have an enforcement role. Each plant's manager reports directly to the Union as in the following illustration of the institutional arrangement that could be followed to ascertain the proper operation of the plants, and assist the implementation of the EMP. The coordination with the Beirut and Mount Lebanon Water and Wastewater Establishment is also important since they are responsible for wastewater monitoring in their new mandate.

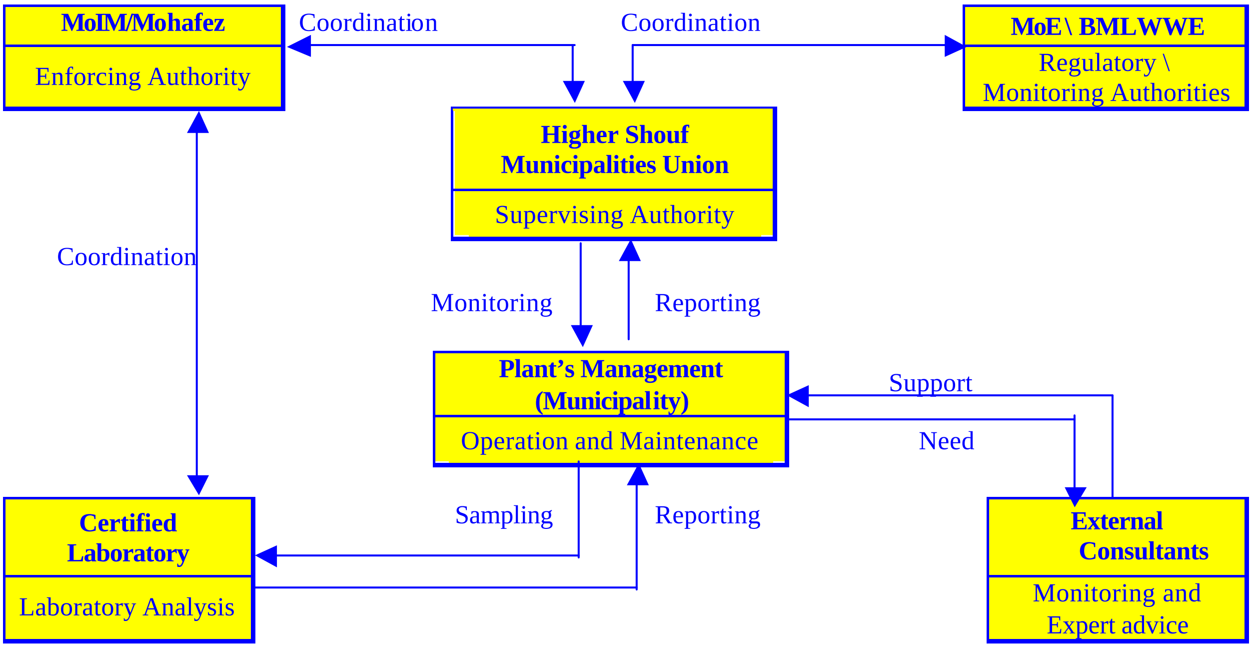


Figure I. Proposed Institutional Setting

1. INTRODUCTION

1.1. THE OVERALL CONTEXT

Lebanon has recently made significant progress towards sustainable development, and has placed more attention to environmental matters and the need to reduce the burden on the environment. The Ministry of Environment (MoE) has been able in the last 11 years to improve considerably its capabilities to fulfill its main role of protecting the environment from the various sources of pollution. Financed by international organizations, several working units within the MoE are setting new environmental standards, building an informational database for the country, and providing the framework to prevent further pollution to widespread in Lebanon.

In particular, the Unit of Planning and Programming (UPP) has revised and further developed the draft Decree for Environmental Impact Assessment (EIA) that is being considered for ratification by the Government. The draft decree states that any planned project that could cause significant environmental impacts should be subject to the preparation of an EIA that would anticipate these impacts and allow provision of mitigation measures to minimize the significance of these impacts, or even eliminate their likelihood. The draft decree also states that projects that could have some impacts on the environment should undergo an initial impact assessment.

1.2. BACKGROUND AND RATIONALE

Recent government initiatives in the fields of solid waste and wastewater management in Lebanon have primarily covered major cities and urban areas in the country. The Integrated Solid Waste Management Plan (ISWMP) that serves the Greater Beirut Area (GBA) and the National Wastewater Management Plan (NWMP) illustrates this challenge, for example. Limited achievements have been experienced so far in rural areas except for community-based initiatives financed primarily by international donors.

The environmental pressure experienced in Lebanese rural areas can be illustrated by the fact that approximately 700,000 tons of municipal solid waste (MSW) and over 100 Mm^3 of raw municipal sewage are directly disposed off in the environment every year (MoE/Ecodit, 2002). A wide range of environmental, public health and socio-economic impacts result from the current situation, some of which are listed below:

- *Contamination of water resources*: Lebanon's groundwater resources are mainly of karstic nature (over 75 percent of the resources), which offer limited possibility for natural attenuation of pollutants before reaching water resources; recent surveys and studies have shown that over 90 percent of the water resources below 600 meters of altitude are contaminated (Jurdi, 2000); surface water streams are also affected by the direct discharge of untreated wastewater. As water becomes polluted, expensive treatment to make it fit for use will inevitably lead to the increase in the price consumers will have to pay when privatization of water services occur and mechanisms such as full-cost accounting are adopted to set water prices.
- *Increased health problems among the population*: inadequate disposal of solid waste and wastewater lead to the release of numerous organic and non-organic contaminants that can eventually reach human beings through diverse pathways including direct ingestion of contaminated water, ingestion of crops contaminated with polluted irrigation water and inhalation of polluted air (from open waste burning activities); for example, it is estimated that 260 children die every year in Lebanon from diarrhea diseases due to poor sanitary conditions leading to the consumption of polluted water (MoH, 1996; CBS/Unicef, 2001).
- *Negative impact on local economic activities*: uncontrolled spread of solid waste and wastewater in valleys, water courses and along roads negatively affects economic activities such as those related to tourism development or eco-tourism by reducing the attractiveness of these areas; similarly, irrigated areas can be at risk if the source of irrigation water is polluted due to poor waste management practices, thus potentially affecting the agriculture sector in some areas; additional economic impacts are attributed to poor health conditions that can affect human productivity in addition to increasing social costs. *It has been recently estimated that the cost of inadequate potable water quality, sanitation, and hygiene (largely due to inadequate waste management) could exceed 1 percent of national Gross Domestic Product (GDP), or as much as 170 million USD per year (World Bank/METAP, 2003).*

Overall development constraints and obstacles in Lebanon do not favor government assistance to rural areas. Political turmoil, regional instability, and huge public debt are affecting the smooth progress of planned projects in the country, most of which are stagnant with little achievement being made. This has lead for instance to the removal of the Solid Waste Environmental Management Plan (SWEMP) financed by the World Bank (WB), which has experienced limited progress since its inception in the late 1990s.

There are potential risks associated with poor waste management practices in rural areas, aggravated by the limited level of assistance from the central government. The result is that most of the rural areas in Lebanon are deprived of adequate sanitary infrastructure. A more consistent response with USAID strategic objectives would be to look for individual or cluster solutions.

A recent survey on waste management practices in 111 villages outside GBA (El-Fadel and Khoury, 2001) highlighted the following major challenges, in decreasing order of importance, budget deficit, lack of technical know-how, lack of equipment, lack of employees, negligence, mismanagement, lack of land and lack of public participation. These can be summarized in two major categories: 1) limited resources (financial and human) and 2) limited technical skills (technical know-how, management, and environmental awareness).

Another important issue highlighted by the survey was the high level of co-disposal of hazardous and special waste stream (over 75 percent). This significantly increases the health risk associated with poor MSW disposal. Rural areas do not have the needed infrastructure to deal with special wastes such as those generated by olive press mills, hospitals, or slaughterhouses. An additional challenge posed by these types of wastes is the low volume-generated which do not attract private sector investment for their treatment and/or valorization.

Financial support from international sources have assisted in supplying infrastructure and equipment to rural areas for solid waste and wastewater management, yet, additional challenges have been disclosed and lessons can be extracted from these experiences:

- Limited financial resources in municipalities can lead to poor operation of solid waste and wastewater technologies when funding is over;
- Insufficient training, know-how and/or commitment from municipalities can also lead to poor operation of technologies;

- Poor quality of compost, particularly due to the presence of inert materials, leads to significant problems in marketing the product to farmers; insufficient or no public participation in source separation activities contributed to this problem;

- Limited number of recycling factories in the country and the long distances usually existing between treatment facilities and these factories lead to very high and unaffordable transportation costs. Recyclable materials are poorly marketed to the consumers;

- Lack of public participation and public awareness or consensus can delay or even stop the execution of such infrastructure projects.

Another important challenge that rural cluster development programs may experience, is the need to obtain approval from the government. The government has demonstrated skepticism towards decentralized projects, fearing that these could be a short-term solution leading to long-term problems. Both the Ministry of Interior and Municipalities (MoIM) and the Ministry of Environment (MoE) have shown their reservations with respect to such initiatives, fearing that they could become out of their control due to difficulties in monitoring the performance of scattered projects across the country.

Implementing sustainable infrastructure projects in Lebanese rural areas requires a multi-disciplinary and clearly oriented approach with a long-sighted vision in order to overcome all the constraints presented above. Figure 1.1 summarizes the overall situation of rural areas with respect to such infrastructure projects.

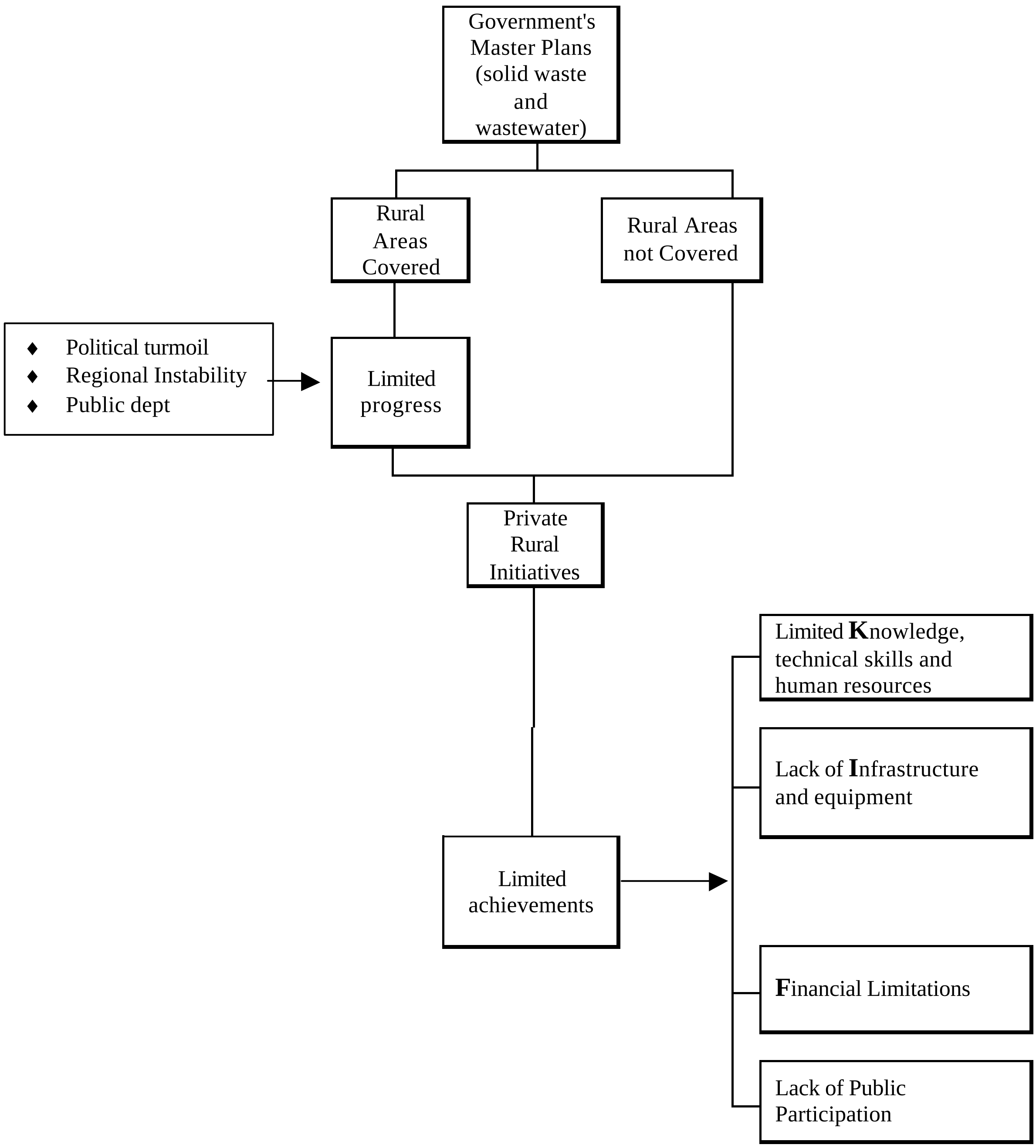


Figure 1.1. Constraints Hindering Infrastructure Development in Rural Communities in Lebanon

1.3. THE PROJECT

This EIA has been prepared to address the potential environmental impacts that could arise from the construction and operation of three ***wastewater treatment plants*** planned to serve the inhabitants of Jebaa, Mrousti, Moukhtara, and Butmeh in the Higher Shouf area, Shouf Caza, Lebanon. Additionally, the EIA evaluates various alternative treatment technologies and presents technical criteria on which to base the selection of the most suitable one. The purpose of the project is to alleviate the severe impacts of uncontrolled sewage discharges into the environment. Proper design selection, construction, and management of the wastewater treatment plants would mitigate such negative impacts.

This EIA will address the wastewater treatment plants planned to be located in Jebaa, Mrousti, and Moukhtara and to serve 1500, 2000, and 3200 persons, respectively. Note that the Moukhtara WWTP will serve also the inhabitants of Butmeh village. While initially it was planned to have a WWTP in each of these villages, they were combined into one plant based on the recommendations of this EIA.

The project initiated by CNEWA/PM (Pontifical Mission) is funded by the USAID for the Union of Higher Shouf under the "Improved Environmental Practices and Policies" program.

1.4. THE PROJECTS LOCATION

The wastewater treatment plants sites were located at the outskirts of each village at down gradient locations in order to convey wastewater to the plant by gravity. The municipalities of Jebaa, Mrousti, Moukhtara, and Butmeh are located approximately 70 to 75 kilometers southeast of Beirut. The proposed location of the plants in each village is presented on respective Geological Maps that are included as Appendix A and on topographic maps presented in Appendix B of this report. The geographical coordinates of the proposed plants location are indicated in Table 1.1. The area of Higher-Shouf under study lies approximately between 183000 and 193000 Northing and 137000 and 146000 Easting.

The sites were proposed and selected by the municipalities and subsequently inspected by CNEWA/PM and ELARD specialists, assuring for down-gradient locations (wastewater conveyed by gravity), and adequate distances from residential areas. These sites were then screened through a process of analysis of alternative sites, if available. The required surface area for the selected locations range from 1000 to 2000 m^2 based on the population number that each plant would serve. The bcation of each site is shown in Photograph 5.1, Photograph 5.3 and Photograph 5.5 in section 5.3; no official land parcels or property survey is present in these selected areas. However, an appointed surveyor has demarcated the land parcels (Appendix D) to be presented in the projects' tender documents (Appendix J).

Table 1.1. Projected Populations, Property Location, and Available Acreage

Area Served	*Geographical Coordinates*	*Actual Population served*	*Projected Population*** Year2014*	*Projected Population Year 2020*	*Available Land area (m^2)**
Jebaa	186800N 140200E	1500	1620	1750	1000
Mrousti	187000N 141400E	2000	2160	2340	1500
Moukhtara-Butmeh	191300N 138500E	3200	3456	3733	2000

*** Donated parcel to the municipality.**

**** Considering the approximate average population growth is 0.8 % (Ecodit, August 2003)**

1.5. THE STUDY AND THE EIA REPORT

This study was prepared in close collaboration with CNEWA/PM, the Union of Higher Shouf Municipalities (UHSM) officials and the municipalities of Jebaa, Mrousti, Moukhtara, and Butmeh. The collaboration has contributed significantly to the overall quality of the study with the identification of the most feasible treatment systems and environmental management practices to be followed at the proposed plants as well as the detection of site-specific needs for each project. The purpose of this EIA study is to ensure that the potential impacts from the installation and operation of the wastewater treatment plants are identified, their significance is assessed, and appropriate mitigation measures are proposed to minimize or eliminate such impacts. Additionally, the EIA has been a catalyst for CNEWA/PM and the municipalities to research other technologies and other vendors thus selecting the most appropriate technology for deployment. Furthermore, the EIA was used as a baseline to set bidding tender document for the selection of highly qualified contractors (Appendix J).

The EIA report is structured in seven main sections in addition to this introduction. Section 2 provides the legislative and institutional framework. Section 3 presents background information to these projects. Section 4 describes each project and their respective associated elements. Section 5 describes the environmental setting at each plant site. Section 6 assesses the impacts. Section 7 presents an environmental management plan (EMP) that will allow managers of the facilities to monitor the treatment activities to ensure process efficiency and environmental safety throughout the project's lifetime, along with impact mitigation measures. Section 8 presents the public participation program implemented to allow direct involvement of the concerned communities in the implementation of the projects.

2. LEGISLATIVE AND INSTITUTIONAL FRAMEWORKS

2.1. LEGISLATIVE FRAMEWORK

The MoE was created by *Law 216* of 2 April 1993 marking a significant step forward in the management of environmental affairs in Lebanon. *Article 2* of *Law No. 216* stipulate that the MoE should formulate a general environmental policy and propose measures for its implementation in coordination with the various concerned public administrations. It also indicates that the MoE should protect the natural and man-made environment in the interests of public health and welfare and fight pollution from whatever source by taking preventative and remedial action. Specifically, the MoE is charged with developing, among others, the following aspects of environmental management:

- A strategy for solid waste and wastewater treatment and disposal, through participation in appropriate committees, conducting studies prepared for this purpose, and commissioning appropriate infrastructure works;

- *Permitting conditions for new industry*, agriculture, quarrying and mining, and the enforcement of appropriate remedial measures for installations existing before promulgation of this law;

- Conditions and regulations for the use of public land, marine and riverine resources, in such a way as to protect the environment;

- Encouragement of private and collective initiatives which improve environmental conditions; and

- Classification of natural sites, landscapes and setting decisions and decrees concerning their protection.

Furthermore, new emission standards for discharge into surface water and air have been established by the MoE (ministerial decision no. 8/1/2001), through the assistance of the SPASI (Strengthening the Permitting & Auditing System for Industry) unit at the MoE, to update the previous standards set by decision 52/1 dated 1996. These standards will be used as a basis to control pollution loads in the country.

Table 2.1 describes the main categories of legislation in Lebanon. In terms of environmental legislation, Table 2.2 presents the existing and proposed legislation pertinent to wastewater treatment plants.

Table 2.1. Categories of Legislation in Lebanon

Laws	Laws are passed by the Lebanese parliament. The council of ministers or deputies can propose a project of law that should pass through the appropriate parliamentary committee. In the case of environmental legislation, this committee is generally the Agriculture, Tourism, Environment and Municipalities Committee, the Public Works, Transport, Electric and Hydraulic Resources Committee, or the Planning and Development Committee. The committee reviews, assesses, and presents the law, with the amendments it introduces, for final approval by the parliament.
Decree laws	The parliament has empowered the council of ministers to issue decree-laws without the prior approval or supervision of the parliament. Decree laws have the same legal standing and powers as laws.
Decrees	The council of ministers issues decrees that have the power of law provided they do not contravene existing laws. The council of state should be consulted before the issuing of a decree.
Resolutions	Ministers issue resolutions without the pre-approval of the council of ministers. Resolutions have the power of law provided they do not contravene existing laws. The council of state should be consulted before the issuing of a resolution.

Table 2.2. Summary of Selected Legislation Related to Wastewater Management

Legislation	***Year***	***Brief Description***
Decree No. 7975	5/5/1931	Related to the cleanliness of residences and their extensions, and wiping out of mosquitoes and flies, and discharges of substances and wastewater.
Decree No. 2761	19/12/1933	Directions related to discharge of wastewater and dirty substances.
Law No. 216	2/4/1993	The Creation of the MoE
Decree 8735	1974	It is forbidden to allow infiltration of sewage waters from cesspools or to leave them partially exposed, or to irrigate vegetables or fruits with their waters (Article 4) It reserves places assigned by each municipality for the treatment of wastes and agricultural and industrial residues (Article 13), empty sewage waters by tankers in special locations by decision of provincial or district governor until drainage canals are built (Article 15) It is forbidden to drill wells to undefined depth with the aim of disposing of sewage water (Article 3)
Ministerial Decision No. 52/1	29/7/1996	Environmental Quality Standards & Criteria for Air, Water and Soil
Law No. 667	29/12/1997	Amendment to Law No. 216, Organization of the MoE
Draft Decree	1998	All agglomerations have to be provided with collecting systems for urban wastewater at the latest by 31 December 2010 for those with a population equivalent of more than 15,000 and 31 December 2015 for those between 2,000 and 15,000 (Article 3) All urban wastewater entering collection systems shall be subject to secondary treatment or an equivalent treatment before discharge. This deadline for achieving this goal is 31 December 2010 for all discharges from agglomerations of more than 15,000 people and 31 December 2015 for those between 2,000 and 15,000 people (Article 4) It should be ensured that urban wastewater treatment plants are designed, constructed, operated and maintained to ensure sufficient performance under all normal local climatic conditions
Ministerial Decision No. 8/1	30/1/2001	Characteristics and standards related to air pollutants and liquid waste emitted from classified establishment and wastewater treatment plants.
Project Decree	7/2000-	Environmental Impact Assessment
Law 444	29/7/2002	Law of the protection of the environment; sets the framework for environmental protection in Lebanon

Table 2.3 summarizes the two main documents that would complement the existing environmental legislation, namely the Law on the protection of the environment (Law 444 dated 2002) and the draft EIA decree. Table 2.4 presents selected standards for discharge into

surface waters (taken from the National Standards for Environmental Quality) that this study has accounted for.

Table 2.3. Law 444 and Draft EIA Decree

Law on the Protection of the Environment (Law 444)
The environmental legislation will be administered by the MoE. Permitting of new facilities with potential environmental impacts will be approved by the MoE in addition to other relevant agencies depending on the type of the project. The application of environmental legislation will be supervised by the MoE; however, the modalities of the supervision exercised by the MoE are not set. Enforcement of legislation is not addressed. It is clear that the MoE will have no enforcement role. The Ministry of Interior will continue to be responsible for the legislation enforcement. A new fund, the National Environment Fund, will be created. The fund covers expenses that should be included in the budget of the MoE. It seems that the establishment of such a fund aims at collecting donations that are specifically targeted to finance environmental projects. Moreover, the fund would also be sustained by the fines and taxes established in the Code. Environmental tax incentives are mentioned for the first time in Lebanese legislation.
The Draft EIA decree (2000)
The MoE decides upon the conditions to be met and information to be provided by a project to receive a permit. The MoE must supervise the projects that are undergoing an EIA. The EIA should contain at least the following sections: institutional framework, description of the project, description of the environment, impact assessment, mitigation measures, and EMP. The EIA is to be presented to the institution in charge of granting a permit to the project depending on the type of the project. A copy of the EIA is sent by this institution to the MoE for consultative and revision purposes.

Table 2.4. Selected Standards for Discharge into Surface Waters

Parameter	***Effluent Concentration ****
pH	6 – 9
BOD_5**	25
COD***	125
Suspended Solids	60
Ammonia-Nitrogen	10
Nitrate	90
Total Phosphorus	10
*Concentrations in mg/L except for pH (unit less) ** Biochemical Oxygen Demand *** Chemical Oxygen Demand	

2.2. INSTITUTIONAL FRAMEWORK

In addition to the MoE, other organizations play a role in environmental protection and management, in particular the Ministries of Public Health (MoPH), Interior and Municipalities (MoIM), Public Works and Transport (MoPWT), Agriculture (MoA), Industry and Petroleum (MoIP), Ministry of Energy and Water and Beirut and Mount Lebanon Water and Wastewater Establishment (BMLWWE). At a regional level, the Mohafaza, Union of Municipalities and each Municipality have direct responsibilities relating to the environment; and the Council for Development and Reconstruction (CDR) is leading the reconstruction and recovery program and has taken over certain responsibility from line ministries in areas with direct environmental implications. Table 2.5 summarizes the main responsibilities and authorities of key institutions in the country.

Table 2.5. Responsibilities and Authorities of Key Institutions in Lebanon

Institution	Water Resources	Urban Planning / Zoning	Standards and Legislation	Enforcement	Biodiversity	Waste Water Discharge
Council for Development and Reconstruction	√	√				√
Council for the Displaced	√					√
Ministry of Agriculture			√		√	√
Ministry of Environment	√	√	√		√	√
Ministry of Housing and Cooperatives		√				√
Ministry of Energy and Water	√		√	√	√	√
Ministry of Industry and Petroleum		√	√	√		√
Ministry of Interior and Municipalities				√		
Ministry of Public Health	√		√		√	√
Ministry of Public Works and Transport	√	√	√			√
Ministry of Tourism		√	√		√	
Beirut and Mount Lebanon Water and Wastewater Establishment	√					√
Union of Municipalities	√	√		√	√	√
Municipality	√	√		√	√	√

3. BACKGROUND INFORMATION

3.1. PROJECTS INITIATION

On April 22nd, 2003 upon the request of the Higher Shouf Municipalities Union, the CNEWA/PM presented a Technical proposal and an Organizational Commitment to USAID seeking funding for the implementation of various Wastewater and Solid Waste treatment plants in that specific region. Subsequently, USAID agreed to finance the implementation of (9) Wastewater treatment plants to serve 12 villages in the Higher Shouf and One Solid Waste treatment plant to serve the (12) villages in the area. On that basis, CNEWA/PM has commissioned Earth Link and Advanced Resources Development, s.a.r.l. (*ELARD*) to perform the EIAs for these various projects.

These municipalities include Moukhtara, Butmeh, Maasser el Shouf, Khraibeh, Aammatour, Ain Qani, Baadaran, Haret Jandal, Niha, Bater, Mrousti, and Jebaa. All twelve villages are located to the East of Barouk River. Land elevations range between less than 800 m and 1250 m above sea level. The wastewater treatment plants were planned initially to be located in nine of these villages, namely, Aammatour, Moukhtara, Butmeh, Bater El Shouf, Niha, Jebaa el Shouf, Mrousti, El Khraibeh and Maasser El Shouf. The plants would serve total design populations of approximately 25000 that might reach 27000 by the year 2013 and 29000 by the year 2023. Moreover, 43 Km of sewage network will be constructed over the union villages to reach the various treatment plants.

3.2. IMPORTANCE OF THE PROJECT

Currently, untreated sewage generated within the Higher Shouf villages is directly disposed off in the environment either through direct discharge into streams and rivers or through septic tanks that can easily leak into ground water aquifers. Butmeh, Mrousti, and Jebaa are typically located over an area that is considered as a recharge zone for many down gradient springs. This situation has caused a continuous degradation of water quality and is exposing the public directly to the associated negative health impacts. Proper conveyance and treatment of sewage is of utmost importance to avoid such impacts, and will be addressed by the construction of wastewater treatment plants (and collection networks) to serve the population of the area.

It is essential to note that potable water is being conveyed into the potable water distribution networks of these villages from a well dug at the Eastern outskirts of the village of Mrousti. Since springs in the area are polluted, most of the villagers rely on the distribution network providing water from wells only. Furthermore, some municipalities were able to install UV Radiation treatment methods for disinfection over their internal network in case drinking water is distributed from a local contaminated spring. Various municipalities in the area performed some sporadic spring water analysis after health problems occurred in the previous years. There are three main factors leading to contamination of springs: 1) the absence of a proper wastewater collection network and treatment in the villages located over the recharge zone of these springs and wells; 2) the karstic constitution of the recharge zone posing no filtration and direct recharge of aquifers; and 3) the abundance of seeping septic tanks in the overlaying area. This third factor leads to the mixing of wastewater with springs water within the various Karstic aquifers. Appendix B includes reports of laboratory analysis on spring water samples confirming the presence of sewerage related contamination within some investigated springs in the Higher Shouf area. It is therefore imperative to treat all the generated sewage in the villages to eliminate the threats of uncontrolled disposal of raw sewage in the environment.

Additionally, wastewater is being discharged directly from residences into run-off ditches and storm water galleries, which in turn conveys the wastewater into open land, agricultural fields, and surface water bodies. This situation is evident in most of the villages in higher Shouf area where raw sewage is discharged into winter channels subjecting the neighboring orchards and agricultural fields to potential hazards, diseases to farmers and the consumers as well, (Photograph 3.1). Moreover, the geological nature of these winter channels, most being tributaries to Barouk River, allows wastewater to infiltrate easily without any sort of natural filtration to the karstic springs underneath.

Photograph 3.1. Discharge of Wastewater in winter channels downstream to Mrousti village

3.3. OBJECTIVES OF THE PROJECT

The main objective of the project is to provide the necessary means to treat sewage generated at the villages of the study area such as Moukhtara, Butmeh, Mrousti, and Jebaa to halt the current practices of uncontrolled disposal of raw sewage in the environment. These practices are posing risk to the public health and the environment, mainly through the contamination of potable water, the groundwater, and associated springs as well as affecting agricultural production. An additional objective is to reduce disease vectors and halt the nuisance associated with open disposal of raw sewage onto roadways and open trenches resulting in the generation of odors, mosquitoes and other insect populations. The concern of the Union of Higher Shouf and the municipalities for the health of the public, the protection of the environment and their drive for developing local tourism is the driving force behind these projects.

3.4. THE EXECUTING OFFICE

The Union of Higher Shouf, the various concerned municipalities all along with CNEWA/PM are the responsible authorities with respect to the proper construction and operation of the plants. They will oversee the works and ensure its execution and operation according to specifications.

4. DESCRIPTION OF THE PROJECT

4.1. GENERAL DESCRIPTION OF THE PLANT

In general, the proposed wastewater treatment plants in the Higher Shouf Area employ typical secondary biological wastewater treatment schemes such as the case of the planned wastewater treatment plant in Moukhtara. However, the case of Jebaa and Mrousti had special considerations since these villages are located over an area considered as the hydrological recharge zone of down gradient springs. This important fact subjected the planned treatment plants to strict effluent quality and operation measures in order to reach advanced wastewater treatment standards.

For domestic wastewater, the major objective of biological treatment is to reduce the carbonaceous BOD (Biochemical Oxygen Demand), coagulate "non-settle-able" colloidal solids, and stabilize organic matter. The wastewater treatment plants in the selected villages employ mainly, to reach secondary treatment standards, aerobic treatment systems of both suspended and attached growth types: a Trickling Filter (TF) followed by an Extended Aeration Activated Sludge (EAAS) system. However, in the case of plants that are located over a hydrological recharge zone, advanced treatment was imposed. This level of treatment consists of additional disinfection, media filtration, and activated carbon filtration to further reduce the BOD load, suspended solids level, nutrients level and eliminate the bacteriological contamination of the effluent that will be mainly discharged back into winter channels that lead eventually to the Barouk River.

The wastewater treatment plants are mainly located at the Western down gradient outskirts of the villages. Design population of each village is specified in Table 4.1, whereas the contribution to the total inflow of raw sewage to the treatment plants in each village is summarized in Table 4.2.

Table 4.1. Present and Projected Populations for the village Being Served by Treatment Plant

Municipality	*Present*	*Year 2014**	*Year 2024*
Jebaa	1500	1620	1750
Mrousti	2000	2160	2340
Moukhtara-Butmeh	3200	3456	3733

* Considering the average population growth 8/1000 per year (Ecodit, August 2003)

Table 4.2. Contribution from the village to the total inflow of raw sewage to the treatment plant

Municipality	*Present Raw sewage (m^3/Day) **	*Raw sewage(m^3/Day) in 2014*	*Raw sewage (m^3/Day) in 2024*
Jebaa	225	243	263
Mrousti	300	324	351
Moukhtara-Butmeh	480	519	560

* Water consumption per Capita is 150 Liters/day

The level of treatment of wastewater also depends on the nature and characteristics of the influent. Table 4.3 characterizes wastewater as weak, medium or strong according to contaminant loads. Based on actual samples taken in the study area, the average concentrations of basic wastewater quality parameters are as follows:

BOD_5:	240 mg/l
SS:	240 mg/l
Ammonia:	50 mg/l
Total Phosphorous:	12 mg/l

Table 4.3. Characterization of Raw Wastewater

Parameter	Weak	Medium	Strong
BOD_5 (mg/l)	110	220	400
TSS (mg/l)	100	200	350
N_{total} (mg/l)	20	40	85
P (mg/l)	4	8	15

Source: Journey, W.K.

This study considers different processes, and evaluates different treatment systems. Rather than assessing the plausibility of one treatment system, the study presents an objective evaluation of alternatives and provides CNEWA/PM and the municipality with technical criteria to select the most suitable system for adoption. Moreover, the study was successful in advising the client to use an attached growth treatment system (Trickling Filter) along with the suspended growth treatment (EAAS). This essential design modification can reduce the normally high-energy requirements of an EAAS system.

4.2. PROCESS THEORY

The treatment of municipal wastewater depends on natural processes such as gravity to clarify an effluent or microorganisms to digest the biodegradable organic content. Pathogens are removed through natural die-off and competition, through providing adequate detention time and temperature, or through disinfection. Basic wastewater treatment mechanisms include preliminary and primary treatment through screening, sedimentation, and filtration. Secondary treatment relies on the digestion of the biodegradable organic content of wastewater (80% of BOD_5) by aerobic and anaerobic microorganisms. Advanced or tertiary treatment includes further treatment of the effluent in the case of sensitive receiving water bodies and high-risk environmental damage. It includes advanced processes such as disinfection, activated carbon adsorption, filtration, reverse osmosis, distillation, and UV disinfection. Table 4.4 summarizes the uses and various characteristics of the stages of wastewater treatment.

Table 4.4. Description of Wastewater Treatment Stages

	Preliminary Treatment	***Primary Treatment***	***Secondary Treatment: Aerobic / Anaerobic***	***Advanced or Tertiary Treatment***
Unit operations & processes involved	Screening / comminutor Grit removal	Primary clarifier	Anaerobic or aerobic biological reactors: Final clarifier	Secondary Treatment + Additional Disinfection Filter media + Activated Carbon Filter.
Principal application	Removal of large objects Removal of heavy objects: sand, gravel, cinder, etc.	Removal of settleable solids and BOD	Removal of fine non-settleable solids, considerable BOD, some NH_3 & total phosphorus	Further removal of suspended solids when necessary
Land requirements	Minimum	Moderate	Moderate	Moderate
Adverse climatic conditions	-	-	Decreased microbial activity (esp. for anaerobic treatment) Freezing of piping and valves	-
Ability to handle flow variations	Good	Fair	Good	Good
Ability to handle influent quality variation	Good	Good	Good (fair for anaerobic)	Poor
Industrial pollutants affecting process	Minimum	Minimum	Moderate	Moderate
Ease of O&M	Fair	Good	Moderate / Good	Fair
Reliability of the process	Good	Good	Good / Moderate	Fair

4.2.1 Anaerobic Biological Treatment Processes

Anaerobic treatment is the use of biological organisms to degrade or stabilize organic (carbonaceous) material in the absence of oxygen into methane gas (CH_4) and inorganic products such as carbon dioxide (CO_2), orthophosphate (ortho-PO_4^{-3}), hydrogen sulfide gas (H_2S), nitrogen gas (N_2), and ammonia (NH_3). Anaerobic biomass is also generated by this process as is demonstrated by sludge formation. Initially, anaerobic treatment was used for the treatment of sludge produced by aerobic treatment processes as well as meatpacking wastes. Today however, it is being used by high strength organic wastes because of its potentially used to produce energy (methane gas) with lower sludge growth rate.

Anaerobic treatment tends to remove a major portion of the BOD from wastewater, but considerable nitrogenous oxygen demand remains. Although some anaerobic processes may require mechanical mixing, relatively simple available technologies are suitable for regions with limited resources. Depending on the characteristics of the wastewater, anaerobic secondary treatment can achieve 65-85% removal of BOD_5 at 20ºC, and 60-80% removal of SS (Journey, W.K.). With anaerobic treatment of wastewater, the reduction of BOD is relatively lower, but on the other hand, energy input and sludge production is considerably lower. Hence, anaerobic treatment is preferred in developing countries with limited energy resources when the presented conditions are suitable for anaerobic activity.

Optimum anaerobic activity takes place at a pH range of 7-8 (Corbit, 1998). While the optimum nutrient ratio for anaerobic activity is a COD:P:N of 100:1:0.2. This ratio demonstrates the lower requirement of anaerobic microorganisms for nitrogen. Anaerobic digestion also requires the presence of other essential nutrients such as sulfur, iron, calcium, magnesium, sodium, potassium, for microorganism's growth. Higher levels of these nutrients however may lead to toxicity and therefore hinder the treatment process (Table 4.5).

Table 4.5. Inhibition Concentrations of Various Ions

Species	Stimulatory mg/l	Moderate mg/l	Strongly Inhibitory mg/l
Sodium	100 – 200	3500 - 5500	8000
Potassium	200 – 400	2500 – 4500	12000
Calcium	100 – 200	2500 – 4500	8000
Magnesium	75 – 150	1000 – 1500	3000
Ammonia	-	1500 – 3000	3000
Hydrogen Sulfide	-	-	200 - 300

Source: Corbitt, 1998

As for temperature requirements, generally, the higher the reactor temperature, the higher the rate of anaerobic substrate removal and cell decay. Usually, anaerobic reactors should be operated at a mesophyllic range: 25 – 40?C or thermophyllic range: 50-70 C.

4.2.1.1 Anaerobic Reactor Types

Anaerobic reactors may be classified as "suspended growth" when the bacteria are suspended in the reactor, or "attached film" when the bacteria are attached as dense films to solid media inside the reactor. Both types may also be further categorized according to the rate of anaerobic activity into high rate or low rate reactors (Table 4.6). *Low rate* reactors, such as septic tanks, are used for single households or small groups of houses where no wastewater collection system exists. *High rate suspended growth* reactors are used to treat industrial (food industries) wastewater or mixtures of industrial wastewater and domestic. Examples include the Anaerobic Contact Reactor (ACR) and the Upflow Anaerobic Sludge Blanket (UASB). *High rate attached film* reactors use a granular solid medium as a carrier. Though this type of reactor has more efficient COD removal rates, it has not been proven that its use with municipal wastes is as effective as the high rate suspended growth reactor type. As Table 4.6 indicates, the high rate suspended growth anaerobic treatment reactor would be the most appropriate to use in the given situation.

Table 4.6. Summary of Anaerobic Reactor Types

Anaerobic Reactor Type	Description	Removal Efficiency	Operation & Maintenance Requirements	Usage	Example
Low Rate Reactor	Low rate of anaerobic digestion	High SS: 90 – 98 % Low BOD: 40 – 60 % Retention Time: few days	Low	- In the absence of wastewater collection network used with single households or a Group of few houses.	Septic Tank
High Rate Suspended Growth	High rate of anaerobic digestion Microorganisms are suspended in reactor fluid	High SS (>90%) High BOD_5 removal	Moderate	- Food Processing Industry - Combined food processing industry wastewater with municipal sewage - Sustainable - Appropriate for areas with limited resources	UASB ACR
High Rate Attached Growth	High rate of anaerobic digestion Microorganisms grow attached to a solid media in reactor	High SS Highest BOD_5 removal	High: Requires sophisticated feed inlets, high rates of effluent recycle,	- Not appropriate to treat municipal sewage of areas with limited resources	Expanded Fluidized

4.2.1.2 High Rate Suspended Growth Anaerobic Reactors

This section will describe the two types of high rate suspended anaerobic reactors: the Upflow Anaerobic Sludge Blanket (UASB) and the Anaerobic Contact Reactor (ACR).

The UASB process is a high-rate anaerobic suspended growth biological treatment process. Since this treatment process is biological, it is based on the metabolic reactions of microorganisms, which in the absence of oxygen; convert the suspended and dissolved organic load into methane gas and carbon dioxide. The organic matter in the wastewater remains in suspension due to the upward flow of influent into the reactor. However, these “flocs” of suspended organisms tend to settle the moderate up flow velocities forming the sludge. The organic load is trapped under a “sludge blanket” where it is slowly digested. The liquid fraction of the influent passes through the suspended “sludge blanket” at a higher rate and is collected in gutters at the tope of the reactor (Figure 4.1)

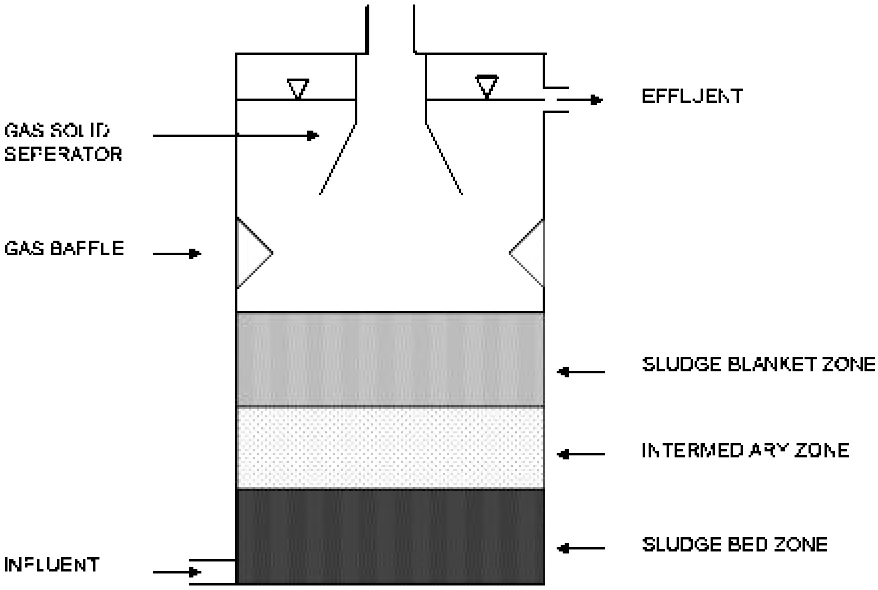


Figure 4.1. Schematic Diagram of a UASB Reactor

The ACR is the anaerobic analogue of the aerobic activated sludge process. It is widely used with industrial wastewater especially in food processing industry with high-suspended solids load. ACRs are not used with municipal wastewater due to the relatively low organic content of such wastewater when compared with industrial wastes. Lower wastewater BOD would necessitate a larger reactor volume to satisfy the required solids retention time. Similar to the activated sludge process, the reactor utilizes mechanical mixing of the substrate to maintain the microorganisms' suspended state as well as recycling of the recovered sludge into the reactor (Figure 4.2). Therefore, ACRs have higher requirements for energy input.

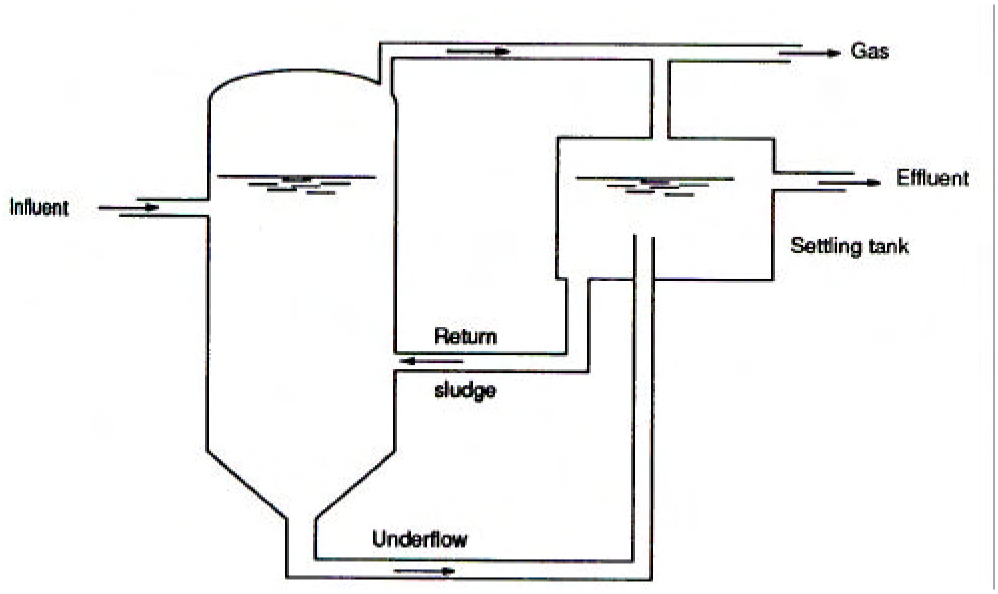


Figure 4.2. Schematic Diagram of an ACR

To compare, UASB reactors can be used with high strength and medium/low strength wastewater from industries such as distilleries, food processing units, tanneries, as well as municipal sewage. On the other hand, ACRs are more commonly used with food industry wastewater rather than domestic wastes. Additionally, using UASB reactors reduces the electric power consumption of a plant when compared to ACRs. UASB reactors are also easier to operate and maintain. Therefore, in regions with limited economic resources, UASB reactors constitute an ideal option essentially under optimal temperature conditions along with minor temperature fluctuations.

4.2.2 Aerobic Biological Treatment Processes

The aerobic biological treatment process relies on the activity of microorganisms to digest the biodegradable organic content of wastewater in the presence of oxygen to release carbon monoxide and gas. Similarly, aerobic treatment may be classified as *suspended growth* type (activated sludge, aerobic ponds) or as *fixed growth* type (Trickling Filters (T.F.), Rotating Biologic Contactors (RBC)).

Unlike anaerobic treatment, aerobic treatment of wastewater typically requires energy input for aeration and produces a higher sludge growth rate. However, aerobic digestion reduces the COD content of the effluent to a further extent (Figure 4.3).

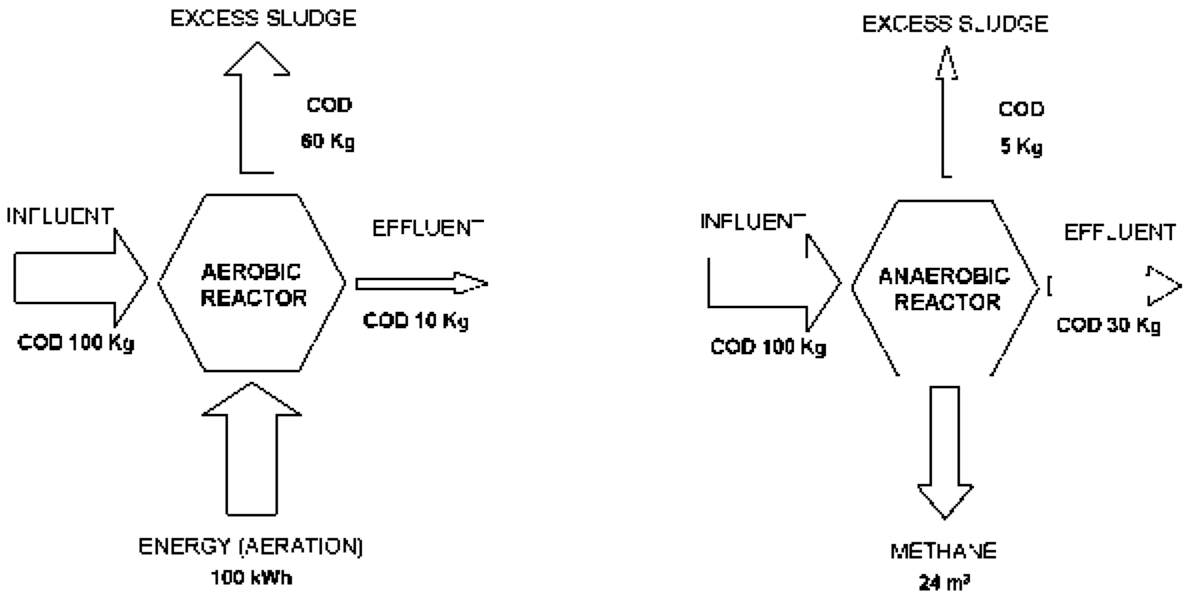


Figure 4.3. Comparison between Aerobic and Anaerobic Biological Treatment (Journey, W.K.)

4.2.2.1 Aerobic Reactor Types

Similar to anaerobic treatment, the secondary treatment of wastewater by aerobic processes may be classified according to the type of reactor used: suspended growth reactors or attached growth reactors. Table 4.7 and Table 4.8 give a detailed comparison of both types of aerobic reactors.

Table 4.7. Comparison of Aerobic Suspended Growth and Attached Growth Reactors

	Aerobic Suspended Growth	***Aerobic Attached Growth***
Unit operations & processes involved	Suspended growth aerobic biological reactor: Conventional or extended aeration activated sludge system	Attached growth aerobic biological reactor: high-rate trickling filters, RBC.
Principal application	Removal of fine non-settleable solids, BOD, some NH_3 & total phosphorus	Removal of fine non-settleable solids, BOD, some NH_3 & total phosphorus
Land requirements	Moderate	High
Adverse climatic conditions	Decreased microbial activity Freezing of piping and valves	Decreased microbial activity Freezing of piping and valves
Ability to handle flow variations	Good	Good
Ability to handle influent quality variation	Good	Fair
Industrial pollutants affecting process	Moderate	Moderate
Ease of O&M	Good	Good
Reliability of the process	Good	Good

Table 4.8. Comparison of the Waste Products of Aerobic Reactors

		Aerobic Suspended Growth	***Aerobic Attached Growth***
Waste products		Sludge (biomass) for conventional; Stabilized and reduced sludge (biomass) for EAAS	Sludge (biomass)
Typical Removal Efficiencies (%)	**BOD_5**	80-85 (Conventional); 80-95 (EAAS)	60-80
	COD	80-85 (CONVENTIONAL); 80-90 (EAAS)	60-80
	TSS	80-90 (CONVENTIONAL); 70-90 (EAAS)	60-85
	TP	10-25 (CONVENTIONAL); 10-15 (EAAS)	8-12
	ON	60-85 (CONVENTIONAL); 75-85 (EAAS)	60-80

4.2.2.2 Activated Sludge (Suspended Growth) Aerobic Reactors

The activated sludge process is an aerobic, suspended growth, biological treatment method. Suspended growth processes aim at maintaining an adequate biological mass in suspension within a reactor, by employing either natural or mechanical mixing. The process is based on the metabolic reactions of microorganisms to produce a high quality effluent by converting and removing soluble organic matter that exerts an oxygen demand. A clear effluent, low in suspended solids, is produced due to the flocculent nature of the biomass. A critical requirement in activated sludge systems is the need of oxygen to stabilize the waste. Four factors are common to all activated sludge systems: (1) a flocculent slurry of microorganisms, also termed Mixed Liquor Suspended Solids (MLSS), in the bioreactor; (2) quiescent settling in the clarifier; (3) activated sludge recycling from the clarifier back to the bioreactor; and (4) excess sludge wasting to control the Solids Retention Time (SRT). The activated sludge process is by far the most widely used biological wastewater treatment process for reducing the concentration of dissolved and colloidal carbonaceous organic matter in wastewater.

The extended aeration activated sludge (EAAS) process is a variation of the conventional activated sludge process. It is a completely mixed process operating at a long hydraulic detention time (18-36 hrs) and a long SRT (20-30 days). Long SRT offers two benefits: remarkably reduced production of stabilized sludge, and greater process stability. However, oxygen requirements are higher for extended aeration activated sludge systems. The system is very robust, stable, and simple to operate, thus rendering it extremely suitable for smaller communities. Moreover, in this case advanced levels of filtration and chlorination are imperative in order to reach complete disinfection of the final effluent to be discharged in the existing winter channel. Figure 4.4 depicts a flow diagram for the complete-mix modification of the activated sludge process. Additionally, Table 4.7 and Table 4.8 summarize the more efficient performance of the EAAS as compared with other aerobic treatment processes.

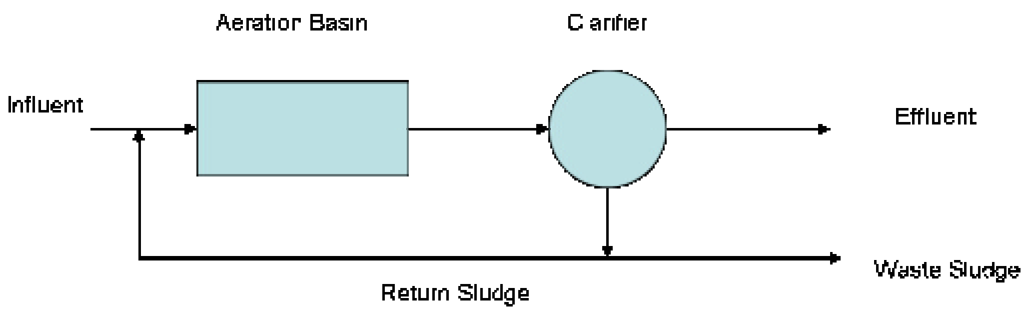


Figure 4.4. Flow Diagram for the Complete-Mix Activated Sludge Process

4.2.2.3 Trickling Filter (Attached Growth) Aerobic Reactor

The trickling filter (TF) process is an aerobic, attached growth, biological treatment method. TFs enable organic material in the wastewater to be adsorbed by a population of microorganisms (aerobic, anaerobic, and facultative bacteria; fungi; algae; and protozoa) attached to the medium as a biological film or slime layer (approximately 0.1 to 0.2 mm thick). As the wastewater flows over the medium, microorganisms already in the water gradually attach themselves to the rock, slag, or plastic surface and form a film. The organic material is then degraded by the aerobic microorganisms in the outer part of the slime layer.

As the layer thickens through microbial growth, oxygen cannot penetrate the medium face, and anaerobic organisms develop. As the biological film continues to grow, the microorganisms near the surface lose their ability to cling to the medium, and a portion of the slime layer falls off the filter. This process is known as sloughing. The sloughed solids are picked up by the under-drain system and transported to a clarifier for removal from the wastewater (Figure 4.5).

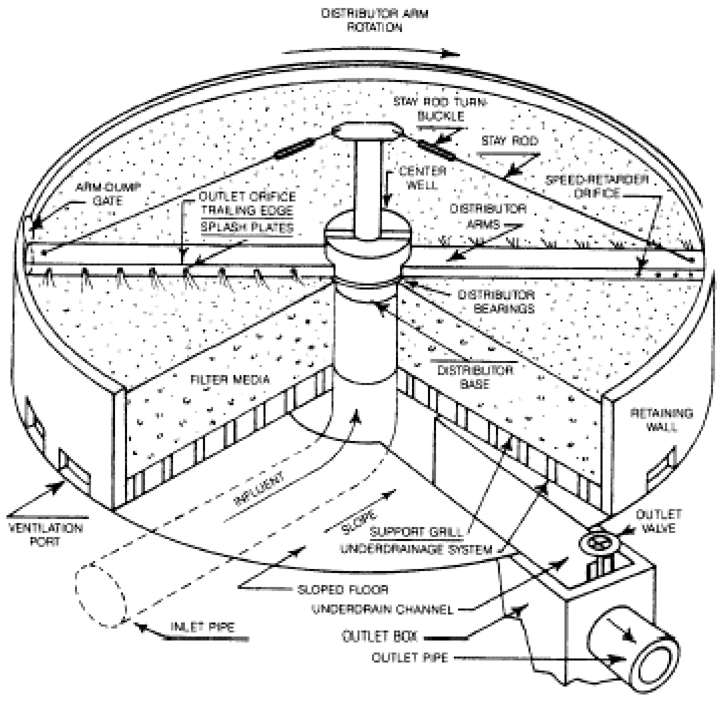


Figure 4.5. Diagram of Trickling Filters

Recent efforts have been made to combine fixed film reactors with suspended growth processes to remove efficiently organic materials from wastewater. For example, the combination of a trickling filter with an activated-sludge process has allowed for the elimination of shock loads to the more sensitive activated sludge while providing a highly polished effluent that could not be achieved by a trickling filter alone. Although the TF process is generally reliable, there is still potential for operational problems. Some of the common problems are attributed to increased growth of biofilm, improper design, changing wastewater characteristics, or equipment failure. Some of the most prominent advantages and shortcomings of this method are listed in Table 4.9.

Table 4.9. Advantages and Disadvantages of Trickling Filters

Advantages	Disadvantages
Simple, reliable process with high degree of performance reliability at low or stable loadings	Additional treatment may be needed to meet more stringent discharge standards
Suitable in areas where large tracts of land are not available for a treatment system	Regular operator attention needed
Effective in treating high concentrations of organics depending on the type of media used, and flow configuration	Relatively high incidence of clogging depending on media type
Appropriate for small - to medium-sized communities	Relatively low organic loadings required depending on the media
Reduction of ammonia-nitrogen concentrations in the wastewater	Limited flexibility and control in comparison with activated-sludge processes
Durability of process elements & Low power requirements	Potential for vector and odor problems
Requires only a moderate level of skill and technical expertise to manage and operate the system	Predation (i.e. fly larvae, worms, snails) decreases the nitrifying capacity of the system

Moreover, the media selected for the trickling filter affects the performance of trickling filters. Plastic media, as illustrated in Table 4.10, has the highest specific surface area and void space. Therefore, such a media allows for higher removal efficiencies and ventilation that is more effective. In addition, tower trickling filters (using vertical strips of filter media) have the highest nitrification capabilities coupled, while those having plastic globe media have the highest BOD loading rates (Table 4.11).

Table 4.10. Properties of Trickling Filter Media

Media	Size (cm)	Specific Surface Area (m^2/m^3)	Void Space (%)
Granite	2.5 - 7.5	63	46
Slag	5 - 7.5	66	49
Redwood	19 x 19 x 0.8	46	76
Plastic	9.5 x 9.5 x 19	83-115	94-97

Source : Corbitt, 1999.

Table 4.11. Nitrification Ability of Various Trickling Filter Media Nitrification

Media	% Nitrification	Loading Rate (g BOD/m^3/day)
Rock	75-85	160-96
Slag	85-95	96-48
Plastic	75-85	288-192
Tower TF	85-95	192-96

Source: Metcalf & Eddy, 1991.

4.3. ANALYSIS OF ALTERNATIVES

4.3.1 Process and Technology Selection

Selection of the most appropriate solution to meet long-term objectives is not a simple and straightforward task. Several factors and parameters must be taken into consideration, including technical criteria, environmental considerations, and economical evaluation. The aim of this section is to weigh the potential of all relevant treatment process alternatives, the system design selection, and the site location. As a result, a sustainable solution can be implemented to treat the wastewater crisis in the study area.

In Section 4.2 (Process Theory), the alternative processes were evaluated in terms of purpose, objectives, usage, and efficacy. However, the optimal process or combination of processes, specifically tailored to treat the wastewater in the selected villages was not determined. Given that anaerobic activities require high temperatures (25 - 30 ºC) to be effective, *ELARD* has recommended against the use of anaerobic processes in the study area, having an average annual temperature of approximately 15 ºC, despite other benefits of anaerobic biological treatment. Furthermore, such solutions were previously adopted in many rural areas in Lebanon all with unsuccessful or insignificant results mainly due to temperature fluctuation. Therefore, anaerobic treatment options were not considered among the studied alternatives. Additionally, since the current situation in the selected villages is not desirable, the "Do Nothing" scenario is not considered a legitimate option.

In the context of analysis of alternatives, six alternative wastewater treatment schemes were screened. Table 4.12 provides a comparison of the different scenarios. The alternatives are:

Alternative 1: Pretreatment alone

Alternative 2: Primary Treatment alone

Alternative 3: Secondary Biological Treatment (Aerobic) through Suspended Growth Process (Activated Sludge)

Alternative 4: Secondary Biological Treatment (Aerobic) through Attached Growth Process (Tricking Filter)

Alternative 5: Combined Secondary Biological Treatment: Attached Growth (TF) followed by Suspended Growth (Activated Sludge) Processes

Alternative 6: Combined Secondary Biological Treatment with additional Disinfection, Media Filtration, and Activated Carbon Filter.

Table 4.12. Analysis of Different Scenarios/alternatives of Wastewater Treatment Schemes

	Preliminary Treatment (1)	***Primary Treatment (2)***	***Secondary Treatment: biological (suspended) (3)***	***Secondary Treatment: biological (attached) (4)***	***Combined Secondary biological (Attached + Suspended) (5)***	***Tertiary Treatment (Attached + Suspended+ Disinfection + Filtration) (6)***
Unit operations & processes involved	Grit removal Grease Trap	Primary Clarifier	Activated Sludge System (EAAS)	High-Rate Trickling Filters	Trickling Filter + Activated sludge system (EAAS) + Final Clarifier + chlorination	Trickling Filter + Activated sludge system (EAAS) + Contact Tanks + Media Filter + Activated Carbon filter.
Principal application	-Removal of large objects -Removal of heavy objects: sand, gravel, cinder, etc. -Removal of grease and oils	Removal of settleable solids and BOD	Removal of fine non-settleable solids, BOD, some NH_3 & total phosphorus	Removal of fine non-settleable solids, BOD, some NH_3 & total phosphorus	Removal of fine non-settleable solids, BOD, some NH_3 & total phosphorus Further removal of suspended solids	Further removal of suspended solids
Land requirements	Minimum	Moderate	Moderate	High	High	High
Adverse climatic conditions			Decreased microbial activity Freezing of piping and valves	Decreased microbial activity Freezing of piping and valves	Decreased microbial activity in aeration tank Freezing of piping and valves	Decreased microbial activity in aeration tank Freezing of piping and valves
Ability to handle flow variations	Good	Fair	Good	Good	Good	Fair
Ability to handle influent quality variation	Good	Good	Good	Fair	Fair	Fair
Industrial pollutants affecting process	Minimum	Minimum	Moderate	Moderate	Moderate	Moderate
Ease of O&M	Fair	Good	Good	Good	Good	Fair
Reliability of the process	Good	Good	Good	High	Good	Moderate

		Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
WASTE PRODUCTS		Screenings, floatables, grit, grease	Sludge (organic & inorganic)	Stabilized and reduced sludge (biomass) for EAAS	Sludge (biomass)	Stabilized and reduced sludge (biomass)	Stabilized and reduced sludge (biomass) Backwash Waste (Filter)
Typical Removal Efficiencies (%)	BOD_5	Small	30-40	80-95 (EAAS)	60-80	60-80 (TF) 80-95 (EAAS)	68-92
	COD	Small	30-40	80-90 (EAAS)	60-80	60-80 (TF) 80-90 (EAAS)	60-90
	TSS	Small	50-65	70-90 (EAAS)	60-85	60-85 (TF) 70-90 (EAAS)	84-97
	TP	SMALL	10-20	10-15 (EAAS)	8-12	8-12 (TF) 10-15 (EAAS)	8-12
	ON	SMALL	20-40	75-85 (EAAS)	60-80	60-80 (TF) 75-85 (EAAS)	80-94
	NH_3-N	SMALL	0	85-95 (EAAS)	8-15	8-15 (TF) 85-95 (EAAS)	85-95 (EAAS) Additional removal through break-point chlorination

The disadvantage of a system with only preliminary and/or primary treatment options is that contaminant removal, in particularly organic, is limited and therefore insufficient. When environmental protection is an issue, the deployed treatment system should include secondary treatment, at a minimum. Therefore, both alternatives 1 and 2 would not be sufficient to treat the wastewater over the selected villages to acceptable water quality levels (Table 4.14).

In general, as long as effluents are properly managed, a secondary treatment based on suspended growth activated sludge is a reliable process that produces acceptable levels of sewage treatment. Alternative 3 consists of utilizing secondary aerobic suspended growth treatment. Although both conventional and extended activated sludge processes could be used, the extended aeration activate sludge (EAAS) treatment was selected for the reasons listed in Table 4.13.

Table 4.13. Advantages of EAAS over Conventional Activated Sludge Treatment

Advantages of Extended Aeration Activate Sludge (EAAS)
Simpler design and operation
Provision of equalization to absorb sudden/temporary shock loads (hydraulic and biological)
High quality and well nitrified effluent meeting secondary effluent guidelines;
Lower production of organically stable waste sludge
Reliable with little need for operator attention
Relatively minimal land requirements and low initial costs;
Nitrification likely at wastewater temperatures of more than 15^{o}C with addition of chemicals
Exists in flexible pre-engineered package plants for small communities

When considering Alternative 3 (EAAS) and Alternative 4 (TF), one can say that both processes would not be adequate and sufficient to use in the study area. A WWTP relying solely on EAAS (Alternative 3) would generate secondary treated effluent of sufficient quality. Yet the costs of operating and maintaining such a plant are much higher than one relying on a TF for treatment (Alternative 4). On the other hand, a TF alone (Alternative 4) would not achieve high levels of treatment performance and would have a relatively high land requirement despite its low lifecycle cost, resistance to shock loading, and ease of operation. Alternative 5 capitalizes on the benefits of TF and EAAS systems by both deploying a TF as a pretreatment to the EAAS, reducing the aeration requirements in the aeration tank and reducing the relatively high land requirement of the trickling filter if used alone. Therefore, it allows for lower power consumption of the EAAS, lower land requirement of the TF, higher treatment efficiency than that of the TF and EAAS individually. This alternative is also preferred due to the ease of maintenance and operation of both the TF and EAAS components. Advanced treatment (Alternative 6) with the additional processes, disinfection (chlorination), media filtration and Activated Carbon filtration generates the highest removal efficiencies of BOD_5, COD, DO, SS, ON, Fecal Coliform and Total Coliform. Though such a treatment process is ideal, its associated maintenance, capital and operational costs are excessive.

In the case of Jebaa and Mrousti, Alternative 5 would not satisfy the discharge limitations of the site. Therefore, the municipal sewage of these villages should be treated to Advanced levels (**Alternative 6**). As for the case of the plant in Moukhtara, serving the population of the latter along with Butmeh village, **Alternative 5** would be acceptable since the site is located over a relatively impermeable formation and the treated effluent will be discharged directly in the Barouk River ensuring proper dilution Table 4.14.

Table 4.14. Analysis of Process Selection Alternatives

Alternative	Concerns
1) Preliminary Treatment	Effluent will not meet National standards for Environmental Quality (ELV: Environmental Limit Values)
2) Primary Treatment	Effluent will not meet ELVs
3) Secondary Aerobic Treatment: Activated Sludge (EAAS)	High Electric Input and Maintenance
4) Secondary Aerobic Treatment: Trickling Filter	Low Treatment Levels, may or may not meet ELVs
5) Combined Secondary Aerobic Treatment: Trickling Filter + Activated Sludge (EAAS) + Chlorination	Effluent will meet ELVs, requires safe discharge site
6) Combined Secondary Aerobic Treatment with Additional Treatment to a Tertiary/Advanced Level: TF + EAAS + Disinfection (Contact Tanks) + Filter Media + Activated Carbon Filters	Highest quality effluent with highest capital, operation and maintenance costs and requirements

4.3.2 Site Selection

The most practical and economical location of the plant would be down gradient with respect to the village or areas being served. As such, the sites are selected in a way to guarantee that sewage is conveyed to the plants by gravity and to cover all the households and institutions in the area, avoiding the need for pumping stations along the sewage collection lines, therefore minimizing operational costs and reducing the potential for a second point source of contamination. Other significant criteria in the selection of a location are the hydrological and geological settings. The distances of the locations from sensitive receptors such as residences and institutions are also considered. The potential proximity of the proposed site to nearby springs or the potential presence of direct hydrological connections with the ground water is highly investigated. Therefore the main parameters investigated in a site selection process are:

- Land availability
- Down-gradient and distant from the area served
- Sewage conveyed by gravity to avoid pumping
- Coverage of the area's households and institutions
- Hydrological, geological, ecological settings
- Institutional and community constraints
- Capability for future upgrading and accessibility of site
- Effluent Discharge options

These parameters among many others are thoroughly investigated and studied since they might easily become major constraints to the implementation of the project and even might render a foreseen solution a problem. Furthermore, mitigation measures and the environmental management plan would be tailored to each selected site based on the constraints and parameters analyzed.

4.3.2.1 Site Selection in Jebaa

The proposed location for the wastewater treatment plant in Jebaa does not permit the discharge of treated effluents into a perennial River. The Barouk River is not at proximity while the quality of effluent should meet the Environmental Limit Values (ELV) for wastewater discharged into surface water that is in turn defined as having a minimum *flow of 0.1 m^3/s* providing proper dilution factor. That does not apply here since the intermittent river nearby the site does not meet the minimum requirements of flow. Therefore, in order to be able to discharge treated effluent in that intermittent river without causing any potential threats from infiltration into down gradient springs, advanced treatment levels were recommended.

Given the limited options for alternative sites since all the proposed sites by the proponent were located over the same area in Jebaa, the following paragraphs present three scenarios for the site location whereby the essential criteria used in the site selection process are evaluated for each scenario (Table 4.15).

Scenario#1: Implementation of a WWTP with Advanced treatment levels located at the identified site by the municipality in Jebaa, which will require:

- Additional capital cost to treat the influent to advanced levels, along with a slight increase in the operation and maintenance cost.
- Implementation of stringent environmental management plan including monitoring of the plant's performance.

Scenario#2: Implementation of a WWTP with a secondary treatment level located at the identified site by the municipality in Jebaa. In this case, the following would apply:

- Over 5 Km of discharge network infrastructure would be required to transport the treated effluent to the perennial Barouk River lying west of the site (maintains a flow >0.1 m^3/s)
- Considerably higher capital cost of establishing new discharge network infrastructure with high potential for network malfunction

- Considerable difficulty of installation due to rough terrains leading to higher installation costs.

Scenario#3: Implementation of a WWTP with a secondary treatment level located on the relatively less permeable Hammana Formation down stream close to the Barouk River. In this case, the following would apply:

- Need to expand collection network infrastructure to convey the sewage from the village for approximately 3 Km to the plant. This would increase the cost by at least $50/ meters of expanded network. Treated Effluents would be then discharged in the Barouk River.

- Increase in the capital cost for expanded discharge and collection networks.

- Additional cost and institutional constraint to purchase a new parcel of land outside the village boundaries to implement a wastewater treatment plant.

- Institutional and social acceptance of the project in the down stream villages. (NIMBY Syndrome)

Scenarios 2 and 3 will incur additional cost for the implementation of discharge network that could be allocated for the implementation of an advanced treatment level within the plant and apply scenario 1. Such additional network would increase capital and maintenance costs and expose sensitive receptors to potential leakages or malfunctioning. Scenario 1 was selected as the best option.

Table 4.15. Summary of Site Selection Process in Jebaa

Parameters	Scenario 1	Scenario 2	Scenario 3
Site Location	Proposed Location by Municipality	Proposed Location by Municipality	Near Barouk River
3URSHUW	Municipal boundary	Municipal boundary	Outside municipal boundary
Treatment Level	Advanced	Secondary	Secondary
Discharge Site	Winter channel over Sannine formation	Barouk River	Barouk River
Geological / Hydrogeological Constraints	Located on a permeable Karstic formation	Located on a permeable Karstic Formation	Located on a relatively impermeable Hammana Formation
Distance from Residential Areas	Approximately 0.5 Km from nearest household	Approximately 0.5 Km from nearest household	Approximately 1 Km from village and nearest household
: LQG'LUHFWLRQ	Residences upwind from site	Residences upwind from site	Residences upwind from site
Collection Network Infrastructure	Close to site, little need for extension	Close to site, little need for extension/ extension of secondary discharge network approx. 2.8-3 km	Has to be extended for collection towards the plant approx. 3 Km.
Capital Costs	Increased due to required Advanced treatment infrastructure Slight increase due to expansion of primary collection infrastructure	High capital cost incurred due the secondary discharge network infrastructure.	High capital cost incurred due to the primary collection network to reach the plant. Increases due to cost of new land parcel
Operational / Maintenance Costs	Increased due to O&M requirements of advanced treatment levels Increased due to stringent environmental management plans and monitoring of the pant	Increased due to maintenance of discharge network	Increased due to stringent environmental management plans and monitoring of the network
Potential of social acceptance	Within the village = acceptable	Within the village = acceptable	Outside village = likely to be rejected
Evaluation & decision	**Preferred & Selected**	Rejected	Rejected

4.3.3 Site Selection in Mrousti

The proposed location for the wastewater treatment plant in Mrousti does not permit the discharge of treated effluents into a perennial River. The Barouk River is not at proximity and the quality of effluent should meet the Environmental Limit Values (ELV) for wastewater discharged into surface water that is in turn defined as having a minimum *flow of 0.1* m^3/s providing proper dilution factor. That does not apply here, since the intermittent river nearby the site does not meet the minimum flow requirements. Therefore, in order to be able to discharge treated effluent in that intermittent river without causing significant potential threats from infiltration into down gradient springs, advanced treatment levels were recommended.

Given the limited options for alternative sites since all the proposed sites by the proponent were located over the same area in Mrousti, *similar scenarios as the ones for the site location in Jebaa* were studied in Mrousti whereby the main criteria used in the site selection process are evaluated for each scenario (Table 4.16).

<u>Scenario#1:</u> Implementation of a WWTP with Advanced treatment levels located at the identified site by the municipality in Mrousti.

<u>Scenario#2:</u> Implementation of a WWTP with a secondary treatment level located at the identified site by the municipality in Mrousti.

<u>Scenario#3:</u> Implementation of a WWTP with a secondary treatment level located on the relatively less permeable Hammana Formation down stream close to the Barouk River.

Table 4.16. Summary of Site Selection Process in Mrousti

Parameters	Scenario 1	Scenario 2	Scenario 3
Site Location	Proposed Location by municipality	Proposed Location by municipality	Near Barouk River
Property	Municipal boundary	Municipal boundary	Outside municipal boundary
Treatment Level	Advanced	Secondary	Secondary
Discharge Site	Winter channel over Sannine formation	Barouk River	Barouk River
Geological / Hydrogeological Constraints	Located on a permeable Karstic formation	Located on permeable Karstic Formation	Located on a relatively impermeable Hammana Formation
Distance from Residential Areas	Approximately 0.6 Km from nearest household	Approximately 0.6 Km from nearest household	Approximately 1 Km from village and nearest household
Wind Direction	Residences upwind from site	Residences upwind from site	Residences upwind from site
Collection Network Infrastructure	Close to site, little need for extension	Close to site, little need for extension/ extension of secondary discharge network approx. 4.5 – 5 km	Has to be extended for collection towards the plant approx. 5 Km.
Capital Costs	Increased due to required Advanced treatment infrastructure. Slight increase due to expansion of primary collection infrastructure.	High capital cost incurred due the secondary dis charge network infrastructure.	High capital cost incurred due to the primary collection network to reach the plant. Increases due to cost of new land parcel
Operational / Maintenance Costs	Increased due to O&M requirements of advanced treatment levels Increased due to stringent environmental management plans and monitoring of the pant	Increased due to maintenance of discharge network	Increased due to stringent environmental management plans and monitoring of the network
Potential of social acceptance	Within the village = acceptable	Within the village = acceptable	Outside village = likely to be rejected
Evaluation & decision	**Preferred & Selected**	Rejected	Rejected

4.3.4 Site Selection in Moukhtara

The proposed location of the plant in Moukhtara serving both Moukhtara and Butmeh inhabitants allows the discharge of treated effluents directly into the nearby tributary leading to the Barouk River, given that their quality meets the Environmental Limit Values (ELV) for wastewater discharged into surface waters (MoE Decision 8/1/2001). Moreover, treated effluent can be used for irrigation of the nearby orchards but since there is an abundance of spring used for irrigation in the area, the main effluent disposal practice will be the discharge into the Barouk River.

Before selecting the final site, a site selection process requiring in-depth investigation of the various hydrological, geological, environmental, engineering, and economical factors was undergone. Nevertheless, in many instances, land tenure issues limit the scope of the selection reducing the range of choices, hence *limiting the options for alternative sites*.

During the preliminary assessment of the needed wastewater treatment plants in the Higher Shouf area, two different plant locations were initially selected, one for each village, Moukhtara and Butmeh respectively.

However, further investigation and assessment of the available settings in both locations as part of the EIA study lead to the selection of Moukhtara site for a common treatment plant to serve both villages. The analysis is presented in Table 4.17.

The investigation studied a variety of scenarios presented in the areas inspected and then graded:

Scenario 1: Implementation of two separate treatment plants

The first scenario consisted of implementing two different plants each located in a village. Nevertheless, due to the tight hydrological and geological settings present at Butmeh site, it is imperative that the discharged effluent from such a plant undergo advanced treatment level.

Scenario 2: Implementation of two separate treatment plants + (3 km secondary effluent pipe)

The second scenario is similar to scenario 1 however; in this case, a secondary level treated effluent will be conveyed through a 3 km pipe from Butmeh plant downstream below the level of springs present in Moukhtara and consequently discharge in the perennial Barouk River. That is essential because Butmeh is located on a Karstic formation considered a recharge zone for the underground aquifer and springs located in Moukhtara.

Scenario 3: One common plant in Moukhtara for both villages along with an approximate 3 km sewage network pipe connection (12 inch) between Butmeh and Moukhtara.

The third scenario presented the option of building one common plant with secondary treatment levels, down stream to the hydro-geologically vulnerable area. Yet, this option requires the completion of a sewage network linking Butmeh to the wastewater treatment plant in Moukhtara.

Each scenario was analyzed according to various criteria presented in order to select the most appropriate solution.

Table 4.17. Analysis of scenarios for the location and number of wastewater treatment plants for Butmeh and Moukhtara.

	Scenario #1 *2 plants +Advanced treatment level in Butmeh*	*Scenario#2* *2 plants with secondary treatment level + extended secondary discharge pipe from Butmeh to Barouk River.*	*Scenario #3* *One central plant in Moukhtara +sewage network link from Butmeh to Moukhtara plant.*
Impact on Biodiversity / Ecological classification	• Implementation of 2 independent plants • Disturbance / Impacts on 2 locations	• Implementation of 2 independent plants • Disturbance / Impacts on 2 locations	• Implementation of one central plant. • Reduction of disturbance to one location
Geological Setting	• Critical location in Butmeh • Less critical zone in Moukhtara	• Critical location in Butmeh • Less critical zone or formation in Moukhtara	• Located on a relatively impermeable formation (Moukhtara)
Topographical Setting	• Steep slope in Butmeh • Part of Butmeh households would not be included due to gravitational problem for sewage collection • Mild slope in Moukhtara	• Steep slope in Butmeh • Part of Butmeh households would not be included due to gravitational problem for sewage collection • Mild slope in Moukhtara	• Mild slope in Moukhtara • All the households of Butmeh will be included.
Hydrogeological Setting	• Butmeh area is located on the edge of the recharge zone for down gradient springs • Relatively Impermeable zone in Moukhtara	• Butmeh area is located on the edge of the recharge zone for down gradient springs • Relatively Impermeable zone in Moukhtara	• Relatively Impermeable zone in Moukhtara
Closeness to perennial river (discharge)	• No perennial river for discharge in Butmeh • Close to a perennial river in Moukhtara	• No perennial river in Butmeh • Close to a perennial river in Moukhtara	• Close to a perennial river in Moukhtara
Required level of mitigation measures and Environmental Management Plan	• Stringent levels in Butmeh, increased frequency of monitoring. (Advanced treatment levels) • Regular Monitoring in Moukhtara	• Stringent levels in Butmeh (limit leaks) • Regular levels in Moukhtara • Additional monitoring needed for the connecting network (No leaks)	• Regular levels of mitigation measures and monitoring. • Regular maintenance of network from Butmeh to Moukhtara
Ability for Future Expansion or upgrading	• Difficult in Butmeh • Relatively easy in Moukhtara	• Difficult in Butmeh • Relatively easy in Moukhtara	• Relatively easy in Moukhtara

Land required	• Two different land parcels required	• Two different land parcels required	• One central land for both municipalities. • Cost of land shared by both municipalities.
Location with respect to village	• Relatively far from Butmeh village center • Relatively far from Moukhtara village center	• Relatively far from Butmeh village center • Relatively far from Moukhtara village center	• Relatively Far from both villages.
Ease of usage in Irrigation (closeness to Agricultural lands).	• No use in Butmeh • Possible use in Moukhtara	• Conveyed through pipes down gradient to both villages • Possible use in Moukhtara	• Location within abandoned agricultural terraces
Economical justification (allocated budget or investment cost)	• Exceeds allocated Budget for Butmeh (additional cost for advanced treatment) • Within allocated Budget for Moukhtara	• Exceeds allocated Budget for Butmeh (additional cost for setting of secondary network pipes connection) • Within allocated Budget for Moukhtara	• Within the initial allocated budget for both plants
Operation and Maintenance Costs/ monitoring costs.	• Higher Operation and Maintenance costs to reach advanced treatment in Butmeh. • Increased frequency of effluent monitoring leading to an increased O.M. costs in Butmeh especially that the municipality have limited resources. • Regular O.M. cost for secondary treatment plant.	• Regular O.M. requirements for Moukhtara plant. • Butmeh: Increased cost O.M. cost due to an increase in frequency of monitoring to prevent leaks at the level of plant and the secondary network connection	• Distributed O.M costs over both municipalities, according to percent contribution in hydraulic loading of the plant.
Benefits	• Treatment of sewage before discharge into the environment in both cases.	• Treatment of sewage before discharge into the environment in both cases.	• Treatment of sewage before discharge into the environment. • Decreased and distributed costs of O.M. on municipalities • All the households in Butmeh will be hooked to the network to reach a common treatment plant.

The third scenario was selected, construction of one plant to serve both villages. The most practical and economical location of the plant would be down gradient with respect to the villages (areas being served). As such, the sewage is conveyed to the plant by gravity, avoiding the need for pumping stations along the sewage collection lines, therefore minimizing operational costs and reducing the potential for a second point source of contamination.

Other significant criteria in the selection of a location are the hydrological and geological settings and land availability constraints. The distances of the locations from sensitive receptors such as residences and institutions are also considered. The potential proximity of the proposed site to nearby springs or the potential presence of direct hydrological connections with the ground water is also highly investigated.

The proposed location for the plant in Moukhtara permits the discharge of treated effluents directly into a perennial Barouk River. Furthermore, the formation on which the plant will be located consists of a relatively impermeable layer that prevents the infiltration of wastewater into underground aquifers. This selected scenario will allow all the sewage generated in Butmeh to reach the treatment plant as compared to the two separate plants scenarios where part of the households in Butmeh will not be included by the network due to gravitational problems.

4.4. DETAILED PROCESS DESCRIPTION

In the combined TF / EAAS treatment system, raw wastewater flows in to a grit trap where it is screened for floatables, and where litter, and suspended solids can settle. Settled sludge is pumped by the sludge pumping station to the sludge holding tanks for storage and dewatering. The grit trap liquid effluent then flows into a grease trap where the grease component is also collected and transported to the sludge-handling unit. The two compartments equalization tank allow effective buffering of hydraulic shock loads and some anoxic activity prior to the next stage of the treatment in the trickling filter that functions mainly to reduce the high organic loading of the wastewater by serving as an intermediate treatment process upstream of the EAAS. The effluent is trickled from rotating distributor system over solid media (vertical strips of Polyethylene) within the trickling filter. The organic portion of the wastewater is degraded under aerobic conditions by microorganisms, also referred to as “slime” or “biofilm,” attached to the surface of the filter media. The thickness of the slime layer increases due to growth of the microorganisms until the outer layer absorbs all the organic matter and causes the inner layer to enter endogenous growth and lose its ability to cling to the media. This phenomenon, called "sloughing" is a function of both organic and hydraulic loading. Higher hydraulic loads are required to promote sloughing and avoid anaerobic conditions due to filter clogging. Continuous flow of the wastewater to the TF is required to provide food for the treatment organisms and to prevent dehydration of the biofilm. The removal efficiency of the TFs may vary between 60 - 80 % COD, 60 - 80 % BOD_5 and 60 - 85% TSS, 8 - 12 % TP, 60 - 80 % TN, and 8 - 15% NH_3-N.

The TF component of the WWTPs will utilize vertical strips of polyethylene. Such a media will provide a higher surface area for biologic activity than conventional slag or rock media. As a result, the BOD and NH_3-N efficiencies are higher than that of other media. In addition, vertical strip media provides higher ventilation and lower risk of odor generation. When compared to media including plastic alternatives, vertical strips are more durable and easy to maintain.

Following the TF, the treated wastewater then flows into the EAAS where it is aerobically digested by suspended microorganisms while air is mechanically introduced in the reactor. In the EAAS reactor, the previously treated wastewater flows into aeration basin(s) in which microorganisms are mixed thoroughly with organics so that they can flocculate and stabilize organic matter. Aeration is accomplished by supplying oxygen via blowers or aerators. The mixture of microbial flocs and wastewater then flows into a final settlement tank (clarifier) where the activated sludge is settled. A portion of the settled sludge is recycled back into the aeration basin and the grit trap to maintain the proper food to microorganism ratio needed for the rapid breakdown of organic matter. The waste sludge is conveyed to sludge-drying beds for proper treatment and disposal. The effluent from the final settlement tank flows into a chlorine contact tank for disinfection. Effluents produced from EAAS systems are of high quality and well nitrified. Typical removal efficiencies for BOD_5, COD, and TSS are 90-95, 80-85, and 70-95, respectively, as reported in published literature. In cases where advanced treatment levels are implemented, Media filtration and Carbon adsorption systems are integrated to treat further the secondary treated effluent prior to discharge. Table 4.18 shows achievable treatment levels or expected effluent quality with various combinations of unit operations and processes used for advanced wastewater treatment.

Table 4.18. Treatments levels achievable with various combinations of unit operations and processes used for advanced wastewater treatment.

Treatment process	**Typical effluent quality**						
	SS mg/l	***BOD_5 mg/l***	***COD mg/l***	***Total N, mg/l***	***NH_3-N, mg/l***	***PO_4 –P, mg/l***	***Turbidity, NTU***
National Environmental limit Values for discharge into surface water	60	25	125	30	10	5	N.A.
Activated Sludge + Media Filtration	4-6	<5-10	30-70	15-35	15-25	4-10	0.3-5
Activated Sludge + Media Filtration + Carbon adsorption **(selected for Jbaa and Mrousti)**	<3	<1	5-15	15-30	15-25	4-10	0.3-3
Activated Sludge / Nitrification, single stage	10-25	5-15	20-45	20-30	1-5	6-10	5-15
Activated Sludge / Nitrification-Denitrification separate stages	10-25	5-15	20-35	5-10	1-2	6-10	5-15
Metal Salt addition to activated sludge	10-20	10-20	30-70	15-30	15-25	<2	5-10
Metal Salt addition to activated sludge + Nitrification / denitrification + Filtration	<5-10	<5-10	20-30	3-5	1-2	<1	0.3-3
Mainstream Biological Phosphorus removal	10-20	5-15	20-35	15-25	5-10	<2	5-10
Activated Sludge Mainstream Biological Phosphorus and Nitrogen removal + Media Filtration + Carbon Adsorption	<10	<5	20-30	<5	<2	<1	0.3-3

***Wastewater Engineering: Treatment; Disposal; Reuse (Third edition)/ Mectalf & Eddy/ 1991**

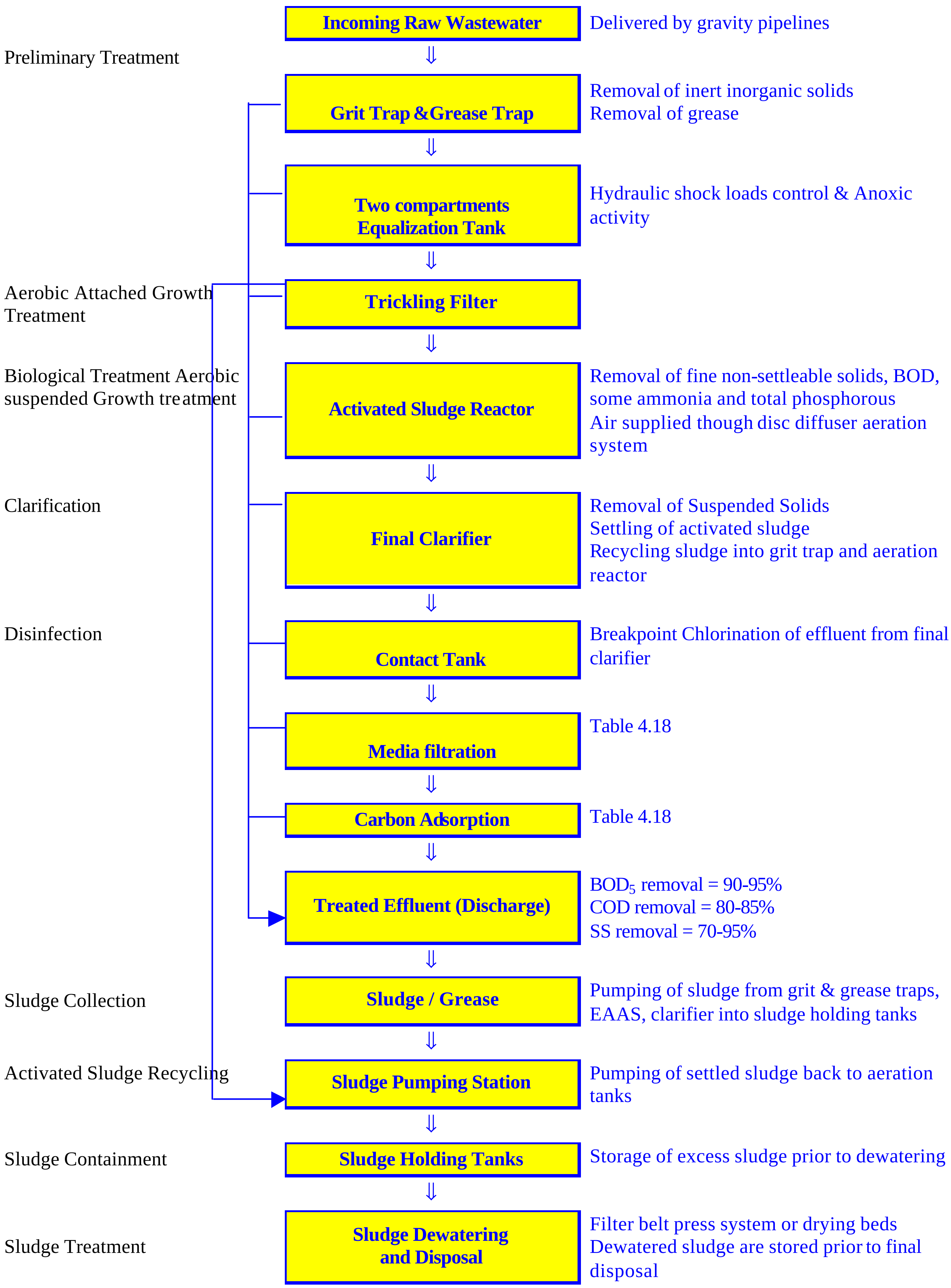


Figure 4.6. Flow Diagram of EAAS Treatment Plant with Advanced Treatment Units

4.5. EFFLUENTS CHARACTERIZATION AND MANAGEMENT

Combined EAAS treatment plants typically generate two main types of byproducts: treated liquid effluent and stabilized waste sludge. Other miscellaneous effluents will include "bulk" solids removed during the preliminary treatment, namely, grit and grease traps. In the case of advanced treatment using media filtration and activated carbon, the saturated media should also be disposed of in an environmentally sound manner.

4.5.1 Liquid Effluent

4.5.1.1 Liquid Effluent Characteristics

The quantity of liquid effluent that will be generated daily is equivalent to the quantity of sewage received by the plants. The average daily volume of generated treated effluent from the wastewater treatment plants by year 2014 and 2024 can be calculated from the projected design population (Table 4.19). In the calculations, an average daily sewage generation of 150 Lit per capita is assumed. It should be noted that quantities of generated liquid effluents would be much less during the first years of operation.

Table 4.19. Average Daily Volumes of Treated Liquid Effluents

Municipality	*Present Raw sewage (m^3/Day)*	*Raw sewage(m^3/Day) in 2014*	*Raw sewage(m^3/Day) in 2024*
Jebaa	225*	243	263
Mrousti	300	324	351
Moukhtara-Butmeh	480	519	560

The expected quality of the liquid effluents varies with the type of adopted treatment technology. However, in the cases where imposed advanced treatment level to reach complete disinfection, would allow the expected effluent quality to meet much stringent standards than the standard values of effluent discharge to surface water. On the other hand, the generated secondary treated effluent will be directly discharged in a perennial River.

4.5.1.2 Liquid Effluent Management

The treated effluent should meet quality standards set in the National Standards for Environmental Quality and thus its disposal in the environment should not cause adverse impacts. However, to avoid any risk of contaminating nearby springs or underground waters, the hydrological and geological settings have been evaluated in Section 5.4 and influence directly the subjected level of treatment in the various locations in this study.

The quality of treated liquid effluent is expected to have lower values than the Environmental Limit Values (ELV) for wastewater discharged into surface waters and completely disinfected in the case of Mrousti and Jebaa WWTPs. The treated liquid effluent will be directly discharged in Wadi el Mansoura Valley (Sannine Formation) located northwest of the proposed plants locations. Since these plants will employ advanced treatment, its disposal in the environment would cause no major adverse impacts, based on achievable effluent quality indicated in Table 4.18. Moreover, *if feasible and needed*, the treated effluent could be used for irrigation purposes for the various types of orchards present in the area only after dechlorination has taken place. Appendices E and F provide respectively the EPA and FAO guidelines for wastewater re-use in the biological environment.

On the other hand, the quality of treated liquid effluent generated at the Moukhtara WWTP is expected to meet the Environmental Limit Values (ELV) for wastewater discharged into surface waters. The treated liquid effluent will be directly discharged in the perennial Barouk River Valley (Mdairej Formation) located west of the proposed Moukhtara plant location.

4.5.2 Sludge Effluent

4.5.2.1 Sludge Characteristics

The estimated volume of generated sludge varies with the type of adopted treatment technology. Typical sludge generation rate for an EAAS system is published to be 6.4 -9.1 Lit/m^3 of wastewater treated. Typical quality of sludge generated after EAAS treatment compared to the standards set in the MoE's Compost Ordinance is depicted in Table 4.20 and Table 4.21.

Table 4.20 Typical Ranges for Chemical Composition of Activated Sludge

Parameter	Typical Range
Total dry solids (%)	0.83-1.16
Nitrogen (N, % of TS)	2.4-5.0
Phosphorus (P_2O_5, % of TS)	2.8-11.0
PH	6.5-8.0
Organic acids (mg/L or ppm as acetic acid)	1,100-1,700

Table 4.21. Typical Metal Content in Wastewater Sludge

Metal	Dry Sludge (mg/Kg or ppm)		
	Range	Median	MoE's Ordinance (grade A)
As*	1.1-230	10	-
Cd*	1-3,410	10	<1.5
Cr	10-99,000	500	<100**
Co	11.3-2,490	30	-
Cu*	84-17,000	800	<100**
Fe	1,000-154,000	17,000	-
Pb*	13-26,000	500	<150**
Mn	32-9,870	260	-
Hg*	0.6-56	6	-
Mo	0.1-214	4	-
Ni*	2-5,300	80	-
Se*	1.7-17.2	5	-
Sn	2.6-329	14	-
Zn*	101-49,000	1,700	<400**

* Metals that are regulated for land application of wastewater sludge
**Values exceeded

4.5.2.2 Sludge Management

Once the plant is operational, detailed sludge characterization and monitoring will be necessary to assess the best disposal option for it. Based on Table 4.20 and Table 4.21, the generated stabilized sludge can be easily used as an organic fertilizer or soil cover in landscapes, in silviculture (woodland exploitation) or in reforestation or even used in quarry rehabilitation. The sludge should not be used for agricultural purposes if high levels of heavy metals are obtained in monitoring results. All mentioned options should be carefully monitored to avoid any negative impacts. Appendix E presents a summary of EPA guidelines that need to be followed to ensure that sludge is applied on soils in ways to minimize adverse impacts on soil quality and vegetation. The agricultural use option is also highly dependent on the demand of such a product in the market and the level of acceptance from the farmers. Furthermore, since a Solid Waste Treatment Plant (SWTP) will be located in the region as part of this USAID environmental improvement programme, the sludge produced can be integrated in the regional composting process. The last option of disposal would be land filling, if an adequate disposal site is available and authorized by the MoE. Therefore, in the case of Higher Shouf WWTPs, three options were presented. Table 4.22 shows the selection process of the best management option or solution for sludge disposal. Option #2 is highly applicable in the case of Higher Shouf area since a SWTP will be implemented concurrently with the WWTPs in the area, so the solution of Co-composting is considered as the best management option.

Option#1: Stabilized sludge used for land application (landscaping activities, quarry rehabilitation)

Option#2: Integration in the regional composting process or Co-composting (Distribution to market)

Option#3: Stabilization and Landfilling.

Table 4.22. Selection of best management practice for generated WWTPs sludge

Sludge Management	***Option#1***	***Option#2***	***Option#3***
Monitoring	Frequent & Regular	Frequent & Regular	Frequent & Regular
Impact Mitigation Measures	High/ requires surface area	High	High / Decrease landfill life
Sustainability of Solution	Sustainable	Highly Sustainable	Less sustainable
Technical & Financial Applicability	Highly Applicable	Highly Applicable since a SWTP will be operational in the Higher Shouf area.	Less Applicable due to lack of landfilling sites
Priority for selection	Second Solution	First Solution	Last Solution

4.5.3 Miscellaneous Wastes

Other debris and solid wastes produced from the plant should be managed similarly to the intended municipal solid waste management plan in the area of Higher Shouf. For Jebaa and Mrousti plants, saturated media will be returned to the suppliers.

4.6. PLANT CONSTRUCTION

The size of a WWTP varies according to the location and the population that it serves as well as the technology implemented. The following information provides an indication of the resources needed to build the plant serving a design population of 3000 persons.

The proposed combined TF / EAAS WWTP in the studied villages will utilize approximately 1500-2500 m^2 in area and serve a design population ranging between 1500-3200. The plants are designed to treat a hydraulic loading ranging from 480 and 225 m^3/day. Appendix C presents a typical architectural map of the proposed WWTPs design. For an EAAS plant serving 3200 capita in the village of Moukhtara, the total volume of excavation will be 1,500 – 3,000 m^3 at a cost of \$3-7/m^3 depending on the type of excavated material. The excavated material will be sent either to quarries where it can be re-utilized (recommended option) or to the nearest landfill for final disposal. A total volume of 250 m^3 of reinforced concrete will be used to construct the plant. Concrete will either be delivered as ready-mix concrete, which will require 32 trucks (8 m^3 each), or be prepared on site. The latter option will require 13 trucks for gravel, 7 trucks for sand, and 3 trucks for cement. Twenty-five tons of reinforced steel will be needed, requiring two additional trucks. Construction work will be phased over 6-8 months, which account for the time necessary to procure electro-mechanical equipment. After completion of concrete works and installation of all electro-mechanical equipment, piping, and fixtures, a testing and start-up period of 2 - 3 months will be provided to ensure that plant is working according to specifications.

5. DESCRIPTION OF THE ENVIRONMENT

5.1. GENERAL SETTING

Two parallel mountainous ranges, Mount Lebanon and Anti Lebanon, separated by the Bekaa plain are the dominating topographic features of Lebanon. These topographic features extend in a NNE-SSW direction. The study area is located on the Western slopes of the southern section of Mount Lebanon, where the lowest elevations coincide with the Barouk River.

The villages of Moukhtara, Butmeh, Jebaa, and Mrousti are all located on the Eastern side of Barouk River, part the Union of Municipalities of Higher Shouf. Land elevations in the study area range between less than 800 m and 1300 m above sea level (Figure 5.1).

A generally good rural road network connects the villages to each other. Some of the presented sites are connected to the main road by an agricultural road and some other sites have no established roads yet. The roads are essential to connect the sites to the main road in order to perform the excavation and building machinery to reach the site easily during plant construction phases and operation phases as well.

Figure 5.1. Detailed topographic map showing the road network in the study area (Scale: 1:200'000)

5.2. METEOROLOGICAL SETTING

The topographic features of Lebanon, in general, influence largely the climate of the country. The climate of the Lebanese coast is of Mediterranean subtropical type, where summers are hot and dry; and winters are mild and wet. On the other hand, snow covers the mountains of the two ranges at times for several months per year. The two mountain ranges tend to have a cool and wet climate in contrast to that of the coastal zone.

Meteorological information including primarily precipitation, ambient temperature, as well as wind direction and speed, are essential data for adequately assessing environmental impacts. Unfortunately, meteorological records are seldom available, except for few locations in the country where stations are operating, in particular the Beirut International Airport (BIA) and the American University of Beirut (AUB) stations. Recently, new stations have been installed across different regions of the country, providing a better coverage of meteorological parameters. Examples include stations installed in the first quarter of the year 1999 in the Barouk region and in the Deir El Qamar village. Currently these stations record temperature, humidity, and precipitation, and are closest to the study area.

5.2.1 Precipitation

The two mountain ranges of Lebanon are perpendicular to the path of atmospheric circulation. They intercept humidity and receive high rainfall compared to areas with similar locations (Figure 5.2). Figure 5.3 depicts monthly rainfall distribution from data collected at the AUB station (between 1996 - 1998 and between 1877 - 1970) at the Jdeidet El Shouf station, which is located towards the Northwestern side of the Barouk River facing Moukhtara (between 1944 - 1970) and Gharife located to the Western side of the Barouk River (between 1965 - 1970). Precipitation data was obtained from BIA records, Service Météorologique du Liban (1977) and from AUB records. The following observations can be made:

- The total annual precipitation is 975, 1,215, 660.3, and 887 mm at Gharife (1965-1970), Jdeidet El Shouf (1944-1970), AUB (1996-1998), and AUB (1944-1977), respectively.
- Precipitation patterns show large seasonal variations with more than 80 percent of the annual rainfall typically occurring between November and March.
- A marked decrease in precipitation levels is noticed at the AUB station, with approximately 25 percent decrease between the two reported periods.

Based on the above observations, about 80 percent of precipitation that is 780 mm in Gharife and 972 mm in Jdeidet El Shouf are probably distributed between November and March. On the other hand, if the same pattern of precipitation levels decrease has occurred in the mountains, similarly to the decrease noticed in the coastal area precipitation in Gharife and Jdeidet El Shouf would be approximately 732 and 912 mm. This is however yet to be confirmed by future data.

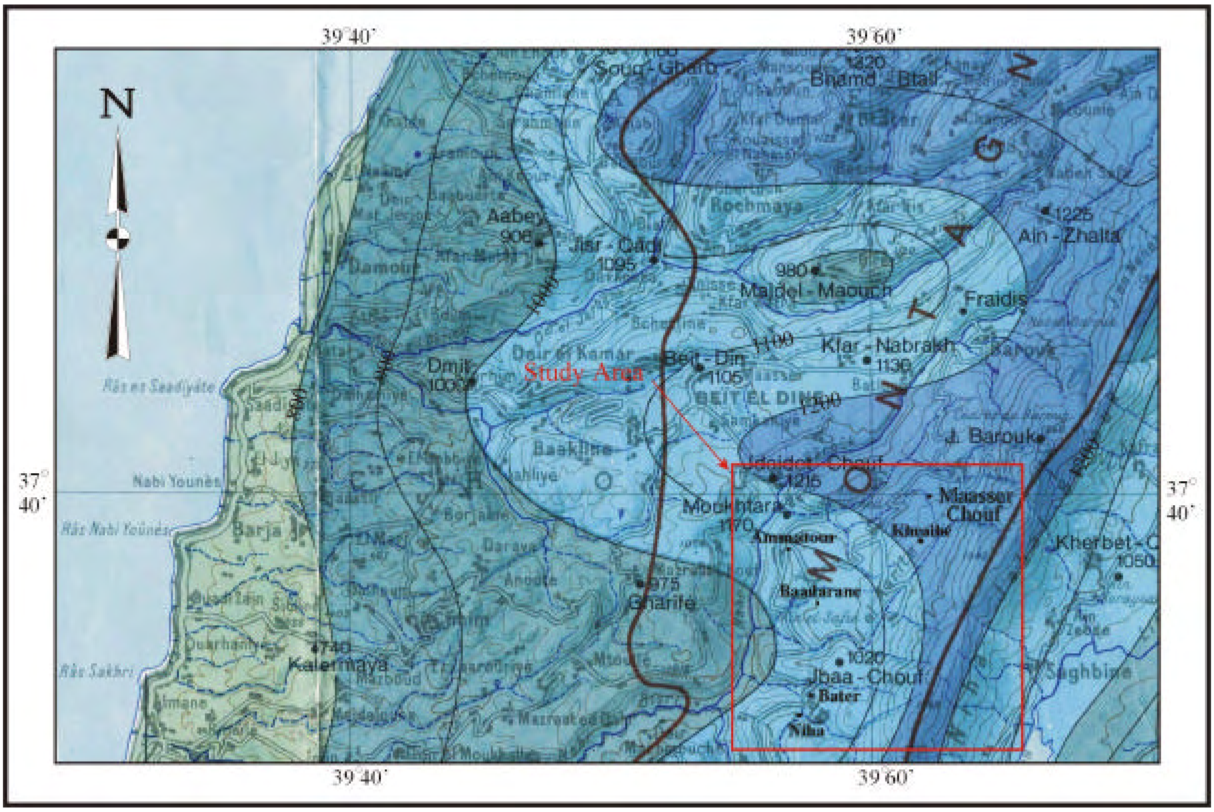


Figure 5.2. Pluviometric Map of the Higher Shouf Area and Surroundings (Scale 1: 200 000) (Service Météorologique du Liban, 1977)

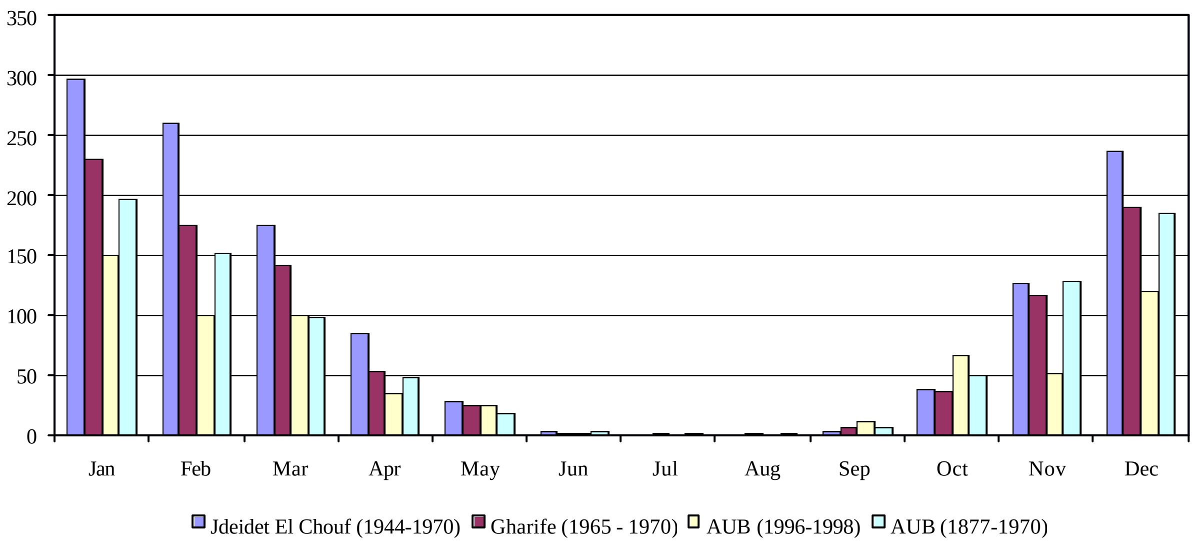


Figure 5.3. Precipitation Data from AUB (34 m), Jdeidet El Shouf (770 m) and Gharife (680 m) Stations (Elevations are from mean sea level).

5.2.2 Temperatures

The mean temperature along the coastal plains is 26.7° C in summer and 10° C in winter. The temperature gradient is around 0.57 °C per 100-m altitude (Blanchet, 1976). January is typically the coldest month with daily mean temperatures falling to -4 ºC in the mountains and 7 ºC in Saida, on the west coast. The warmest months are July and August, when mean daily temperatures can rise to 28 ºC in the mountains and 33 ºC on the coast. Figure 5.4 depicts monthly temperature distribution from data collected at AUB station (between 1996 and 1998, and between 1931 and 1970), at Kfar Nabrakh station (between 1956 and 1970) and at Gharife (1964-1970). The Kfar Nabrakh station is located in the extreme northern part of the area. The following observations can be made:

- Average monthly temperatures in Kfar Nabrakh vary between 7.7 ºC in January and 22.4 ºC in August.
- Average monthly temperatures in Gharifie vary between 9.4 ºC in January and 22.2 ºC in August.
- Temperature records did not change significantly at the AUB station between the two-recorded periods.

The average annual temperature is 15.4 and 16.2 in Kfar Nabrakh and Gharifie village respectively. Temperature in the study area does not vary much (Figure 5.4); variation is probably in the order of 1 ºC as documented between Gharifie and Kfar Nabrakh. However, since temperature records did not change much between the two-recorded periods in the AUB station the average yearly temperature in the study area would be approximately 15.8ºC.

5.2.3 Winds

Dominant wind directions are southwesterly; continental east and southeasterly winds are also frequent. The two mountain ranges have a major impact on wind direction, and contribute to reducing the incidence and strength of the southeasterly and northwesterly winds on the mountain-backed shoreline and in the Bekaa valley. Strongest winds are generally observed during the fall season. Wind data is available at AUB and BIA stations, in Tyr, Tripoli, Cedars, Dahr El Baidar, and Zahle. Wind data close to the study area is not available. Dominant wind direction is oriented in the NNE and NE (Service Météorologique du Liban, 1969). Nevertheless, since the study area covers a wide range of settings from valleys to highs, locals were consulted regarding the general wind directions in the proposed location.

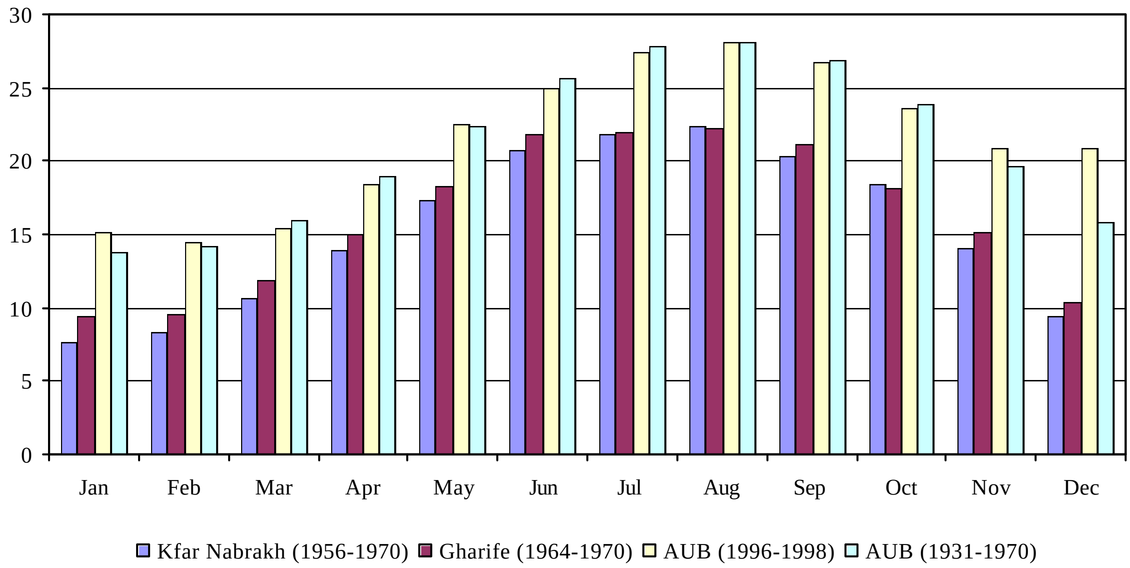


Figure 5.4. Average Monthly Temperature Data from AUB (34 m), Kfar Nabrakh (1020 m) and Gharife (680 m) Stations (Elevations are from mean sea level).

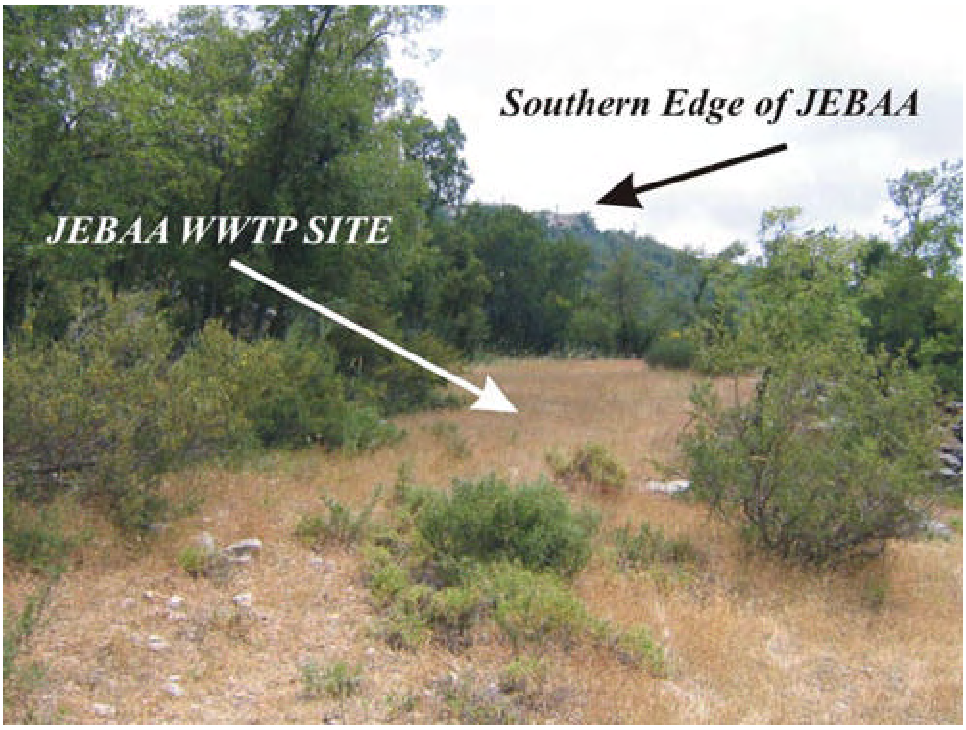
5.3. SITE SETTING

As mentioned above, with the tight collaboration with CNEWA/PM and the environmental consultants, each municipality officials proposed a location for the WWTP treatment plant. The data presented in this section was either collected through field visits, locations assessments, research, and/or in consultation with each municipality officials or local citizens. Climate data were mainly obtained from records from Kfar Nabrach and Gharife stations.

5.3.1 Jebaa WWTP Site

The site is located at the Western outskirts of the village, down gradient to most of the populated area therefore the wastewater would be easily collected by gravity (Photograph 5.1). The average land elevation is approximately 1100 m above sea level. Appendix A presents a Geological Map overlain on the Topographic Map of Jebaa and Mrousti area showing the proposed locations of the treatment plants. The Jebaa site is delineated on its southern edge by a small winter channel that reaches a seasonal river located down stream called Wadi-Hraq-Daas on the Western side of the location coming from Mrousti village direction located towards the Northeast. This intermittent river intersects downstream with the Barouk River at the level of an area called Al-Salleet at an elevation of 473 meters. Average slope inclination of the surface topography is approximately 20%, down sloping in a Northwesterly direction. The proposed site then is located over small terraces overlooking an intermittent river, has the main village road on the Eastern side, and surrounded by Quercus sp. trees. (Photograph 5.2). The site is accessible through an agricultural road that needs to be rehabilitated in order to allow building equipment and machinery to reach the site.

Precipitation in the area ranges between 900 and 1100 mm/year (Service Meteorologique du Liban, 1977). Wind direction varies between orientations of ENE and E (Service Meteorologique du Liban, 1969). Average annual temperature in this area is approximately 15 ^{o}C (Service Meteorologique du Liban, 1977).

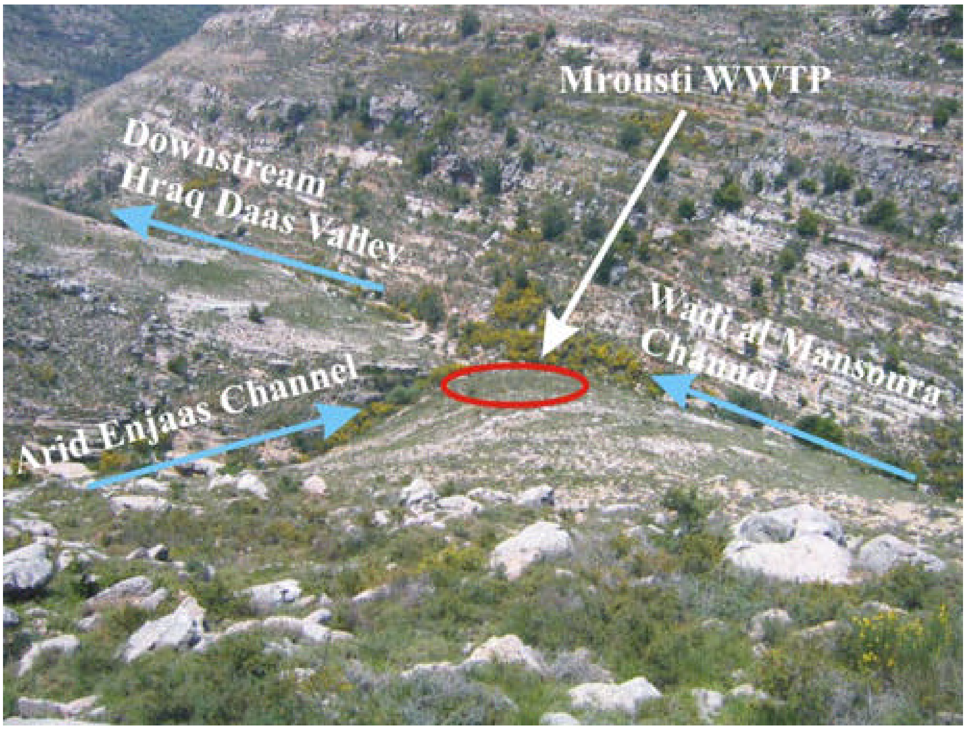


Photograph 5.1. General view the proposed site for the wastewater treatment plant, in Jebaa site located towards the Western outskirts of the village. Photograph looking towards the South direction.

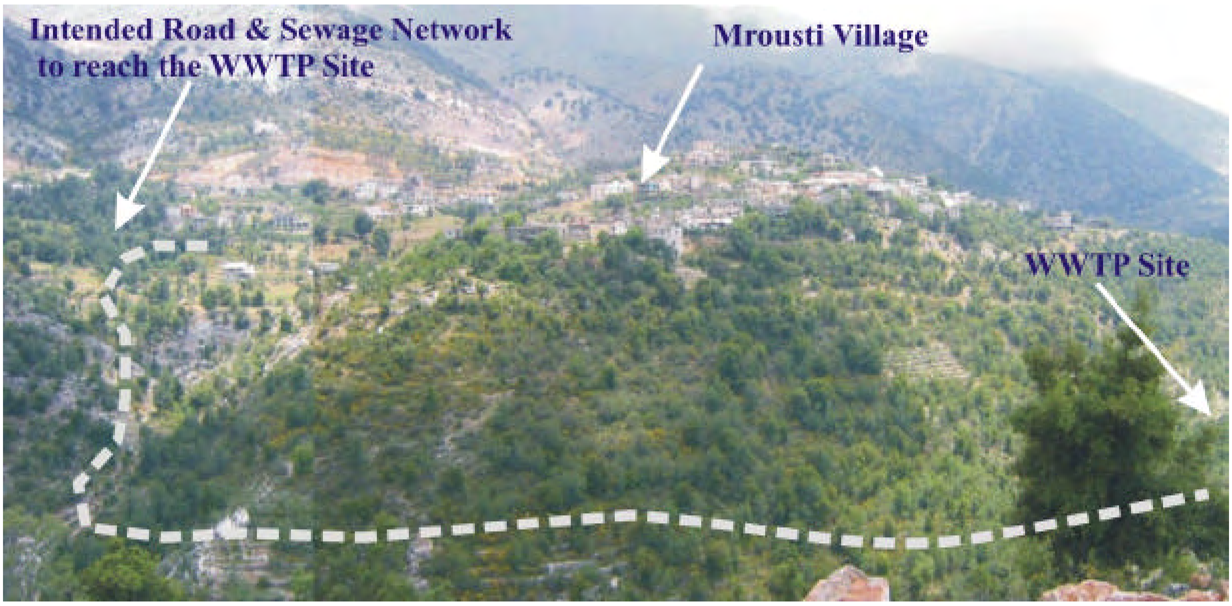
Photograph 5.2. Band of Quercus sp. trees surrounding the site

5.3.2 Mrousti WWTP Site

The WWTP site in Mrousti is located in a valley called Wadi El Mansoura on the Western outskirts of the village, down gradient to the populated area so that the wastewater would be easily collected by gravity (Photograph 5.3). The average land elevation is approximately 1054 m above sea level. In Appendix A, a Geological Map overlain on the Topographic Map of Jebaa and Mrousti area showing the proposed locations of the respective treatment plants. The Mrousti site is located at the level of an intersection between a small winter channel and an intermittent River. The first called Arid En Njaas channel delineates the site on its Southern edge and consists initially of two small watersheds Saqiet Hart Saghir and Saqiet ed Dalil and the second river delineates the site on its western side. Therefore, this second winter channel will reach downstream the seasonal river located on the northeastern slopes of the village of Jebaa called Wadi-Hraq-Daas. Eventually, this intermittent river intersects downstream with the Barouk River at the level of an area called Al-Salleet at an elevation of 473 meters. Average slope inclination of the surface topography is approximately 10% over the site, down sloping in a westerly direction. The proposed site then is located over a parcel overlooking an intersection between two winter channels. However, the site is currently accessible by foot since there is no road that reaches the location; the municipality intends to implement a road along with the sewage network construction phase (Photograph 5.4).



Photograph 5.3. General view the proposed site for the wastewater treatment plant in Mrousti located towards the Western outskirts of the village. Photograph was taken from a cliff overlooking the site.

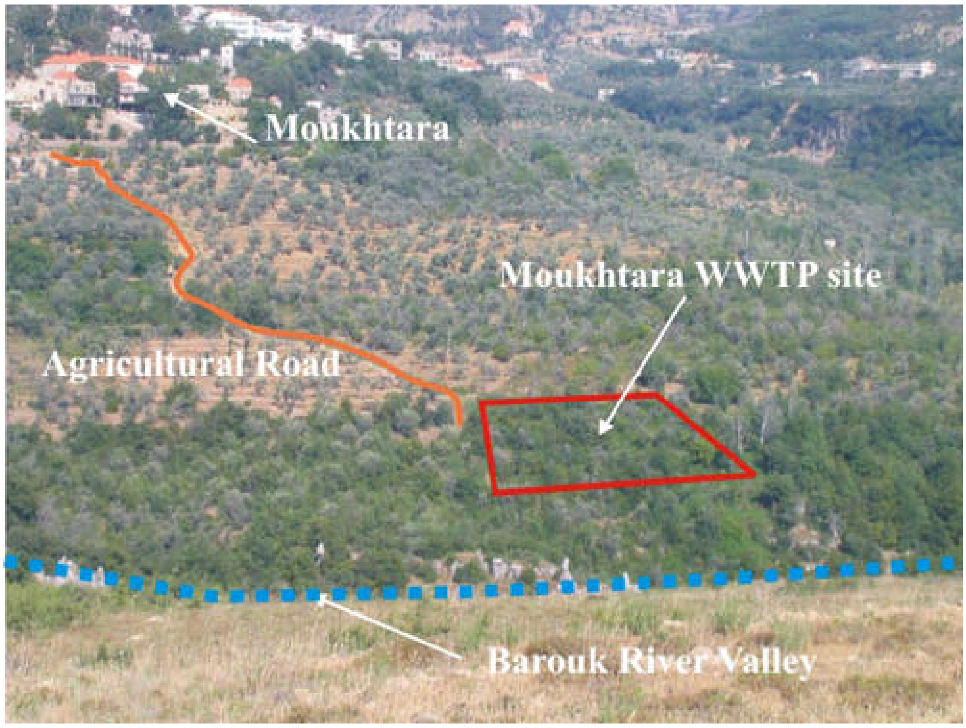


Photograph 5.4. Approximate road and main sewage network location to reach the WWTP site. Photograph looking towards the East direction.

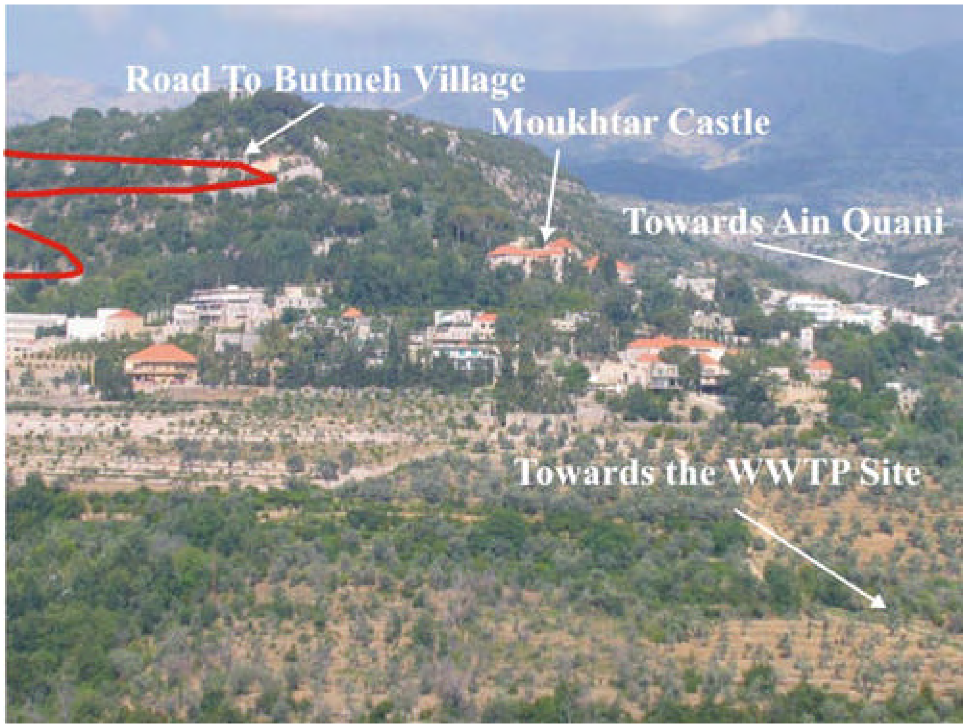
5.3.3 Moukhtara – Butmeh WWTP Site

The WWTP site in Moukhtara is located in a valley overlooking the Barouk River on the Western outskirts of the village, down gradient to the populated area in the villages of Butmeh and Moukhtara so that the wastewater would be easily collected by gravity (Photograph 5.5). The average land elevation is approximately 720 m above sea level. In Appendix A, a

Geological Map overlain on the Topographic Map of Moukhtara and Butmeh area showing the proposed location of the treatment plant in Moukhtara. The Moukhtara site is then located on an area directly overlooking the Barouk River. An intermittent winter channel delineates the site from its Northern side. Average slope inclination of the surface topography is approximately 7% over the site, down sloping in a westerly direction. The site is currently accessible by an agricultural road that requires rehabilitation; the municipality as part of its local contribution to the project intends to rehabilitate the road along with the intended sewage network construction phase. (Photograph 5.6) presents the general view of the villages around Moukhtara.



Photograph 5.5. General view the proposed site for the wastewater treatment plant in Moukhtara located towards the Western outskirts of the village. Photograph was taken from the side of Kahlouniyeh facing Moukhtara, looking towards the East.



Photograph 5.6. General setting around the Moukhtara village. Photograph taken from Kahlouniyeh village looking towards the East.

5.4. GEOLOGICAL SETTING OVER JEBAA & MROUSTI

The geology over these two villages, including subsurface Stratigraphy and structure, was developed based on: 1) review of available maps and literature, 2) analysis of aerial photographs, and 3) geological surveys and site visits conducted by ELARD geologists. The result was the generation of a geological map at a scale of 1:10,000 covering the area of study, reaching approximately eight Km^2 and lying within grid coordinates 186 000 and 188 000 Northing, and 139 000 and 142 000 Easting. The map is included in Appendix A. One geological cross-section (AB) that illustrates the subsurface Stratigraphy and structure, underneath the proposed site in both Mrousti and Jebaa El Shouf and in the study area in general are presented on the map.

5.4.1 Stratigraphy

There are mainly six formations outcropping in the study area. One of the Formations belongs to the Jurassic period while the other five Formations belong to the cretaceous Period. The outcropping formations are described in the following section.

5.4.1.1 Jurassic

5.4.1.1.1 The Bikfaya Formation (J_4)

This formation is outcropping at high altitudes in Mrousti on the Eastern part of the study area. This formation consists of hard micritic limestone. The limestone displays a bluish grayish color on weathered surface, while it is characterized by a white cream color on fresh cut surface. Furthermore, chert nodules are abundant in the Bikfaya formation.

5.4.1.2 Cretaceous

5.4.1.2.1 The Chouf Formation (C_1)

This formation is outcropping in the eastern part of the studied area on both sides of the Mrousti village main road. This formation can be identified because of the presence of pine trees that are a distinctive sign in the sandstone. This formation consists of unconsolidated and consolidated sandstones and ferruginous sandstones. The consolidated sandstones have various types of cements as to mention calcite, quartz, clays, or iron oxides. Clay, lignite, and coal layers exist as inter beds among the quartz sandstones layers. In the study area, the Chouf Sandstone layer has an approximate thickness of 150m. At the top of the Chouf sandstone formation, the sandstone grades into green marl. This change in lithology indicates the transition between the Chouf Sandstone and the younger formation the Abeih Formation.

5.4.1.2.2 The Abeih Formation (C_{2a})

This formation consists in its upper part of yellowish and brownish fossileferous limestone, while it consists in its lower parts, of intercalations of blue and green marls, and yellowish limestone. This formation reaches a thickness of about 75m in the study area.

5.4.1.2.3 The Mdairej formation (C_{2b})

This formation consists in a very distinctive cliff observed on the hills east of the study area. This cliff is formed of hard grayish micritic massive limestone rich in calcite veins. This formation is approximately 75m thick.

5.4.1.2.4 The Hammana formation (C_3)

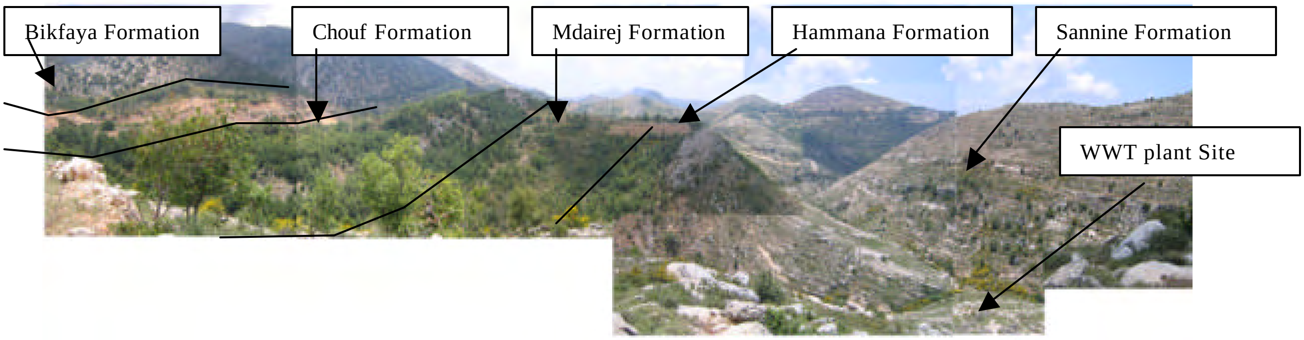
This formation outcrops mainly in El Mounchar, El Qattara, East to Mrousti Village, and in part of Ouadi Hraq Daas in the western part of the study area in Jebaa. It is characterized by creamish to greenish marly limestone. This formation is also highly fossileferous, as molded gastropods and fossilized oysters are frequently found. A distinctive yellowish limestone bed of 25m thickness, known as the Banc de Zummoffen is present in the middle of this formation. This formation has a thickness of approximately 250-300m in the studied area.

5.4.1.2.5 The Sannine formation (C_4)

The Sannine formation outcrops in most of the study area, mainly in Jebaa Ech Chouf, Qalaat Kaouayer, Tallet El Aarid, and Mrousti Village and along the three intersection streams in the valley west to Mrousti Village. This formation consists in its lower levels of marly limestone that grades into thin beds of gray limestone especially along streambeds in the valleys. In its upper part, this formation is composed of massive gray limestone. This formation is highly fossileferous, characterized by remolded oysters' shells as shown on Photograph in Jebaa area. The thickness of this formation in the studied area reaches approximately 600m (Geological Map, Appendix A). The lower limit of the Sannine Formation is characterized by massive limestones and dolomites, above the green or grey marls of the Hammana Formation. (Photograph 5.7).

Photograph 5.7. Photograph taken in Jebaa showing the Sannine Formation characterized by oysters' fossilized shells

Photograph 5.8 shows the succession of Formations from the west to the east in Mrousti Area. It shows the Bikfaya Formation on top followed by the cretaceous formations down to the Valley.

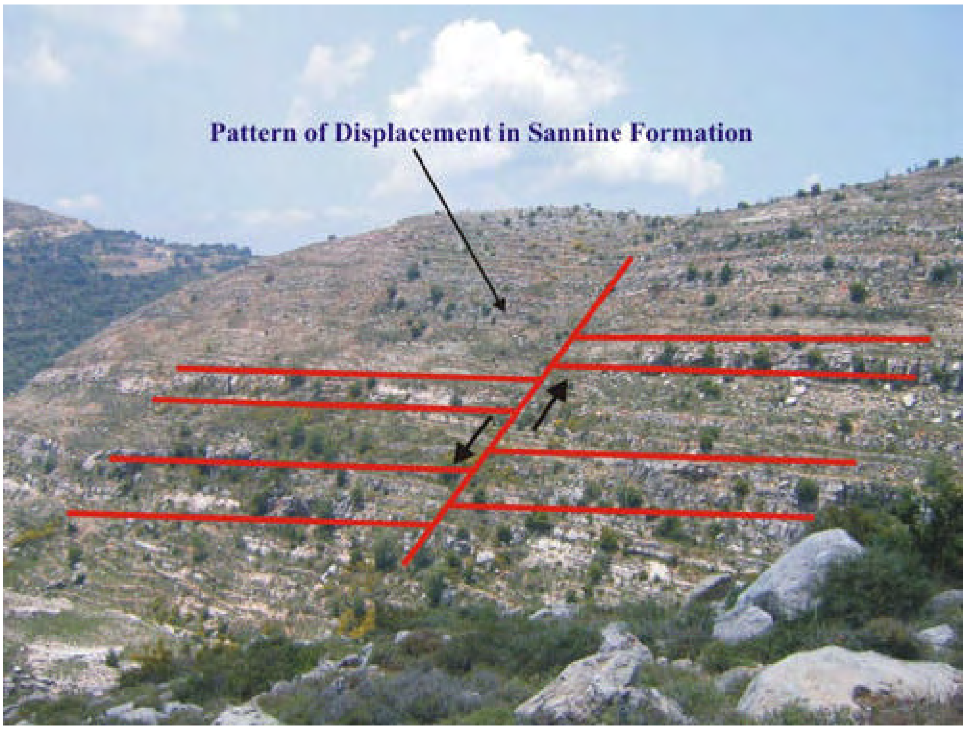


Photograph 5.8: Photograph showing the succession of formations South-East from the wastewater plant site location

5.4.2 Structure

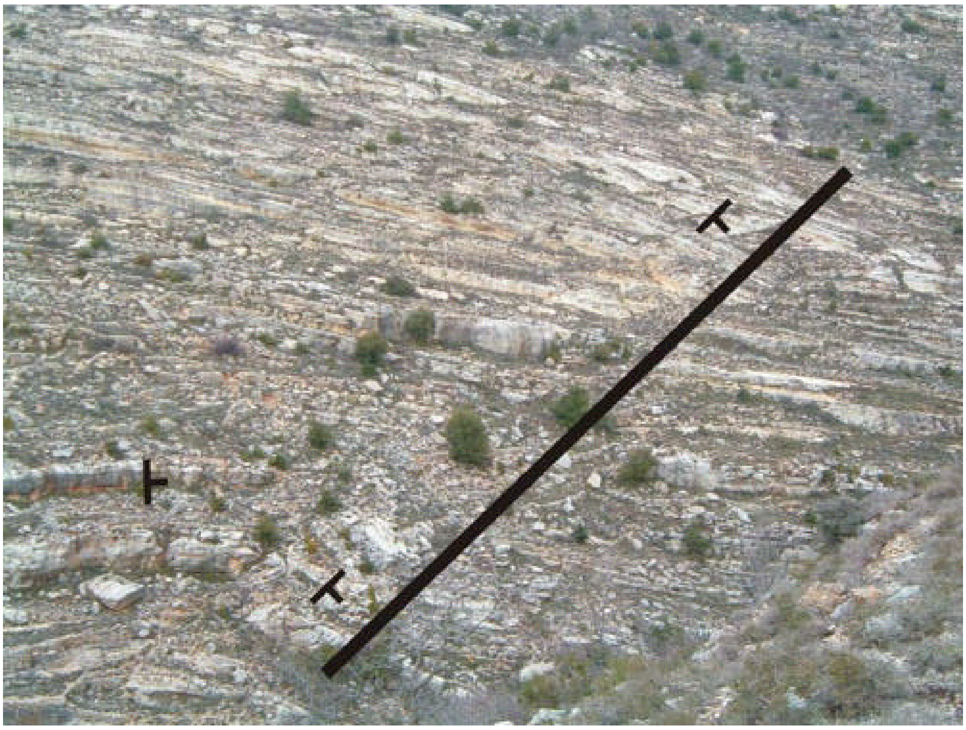
Formations in the study area are dipping generally towards the east at 10º. Structural disturbances mainly through faults and folds have significant influence on the bedding attitude in the study area of Mrousti and Jebaa. Beds dip at angles ranging between 18º and 64º near the disturbance zone of faulting and folding.

There exist two dominant trends for faulting in the study area; faults trends either east west, or northeast southwest. An example of the east-west faults is the fault passing south to Mrousti. It trends in an east-west direction and at varied angles, ranging between 78º and 82º. These types of faults are normal faults with a throw of approximately 20m. The trace of the fault is shown in Photograph 5.9, where small cliffs in the Sannine Formation seem to be displaced from both side of the fault. Another east west fault can also be observed south to Mrousti. This fault is an oblique slip fault that has displaced all the outcropping formations with respect to each other. The amount of displacement can be approximately 70 to 100m.



Photograph 5.9. Fault passing through Qalaa El Kaouayer in Mrousti. Note the displacements occurring in the cliffs belonging to the Sannine Formation.

Photograph 5.10 shows an example of the northeast-southwest faults affecting the Sannine formation in Jebaa Area. No information regarding the motion along this fault could be gathered since it is affecting a single formation. Another northeast-southwest fault could be observed in the valley west to Mrousti Village as well.



Photograph 5.10. Photograph showing the trace of a fault passing north to Jebaa Village facing the location of the wastewater plant, note the variation of dip near the fault trace

5.4.3 Hydrogeological Setting

The hydrogeology of the surveyed area was developed based on: 1) the review of available maps and literature; 2) the Hydrogeological surveys and site visits conducted by ELARD specialists.

5.4.3.1 Aquifers

Two main aquifers were identified, the Mdairej aquifer underlain by the Abeih aquiclude, and the Sannine aquiferous Formation underlain by the Hammana aquiclude.

5.4.3.1.1 Bikfaya Formation

The Bikfaya Formation constitutes an important aquifer of the Jurassic sequence. It is characterized by its high secondary porosity whereby groundwater flow through interconnected fractures, voids and channels.

5.4.3.1.2 Chouf Sandstone

The Chouf Sandstone constitutes a porous aquifer characterized by a relatively fair permeability. The Upper Unit of the Chouf Sandstone consists of marls and clays, which do not hold water and act consequently as a permeable confining unit. Nevertheless, the Chouf sandstone yield remains relatively limited with respect to the karstic aquifers of the study area namely the Upper Cretaceous aquifers.

5.4.3.1.3 Mdairej Aquifer (C_{2b})

Forty-five meters of massive limestone cliff constitute the aquiferous member of the Mdairej Formation. Being located between two aquicludes; namely the Abeih Formation at the bottom, and the Hammana formation at the top, the Mdairej formation has a relatively high water bearing capacity, which remains, however limited due to its relative small thickness. However, its position between two aquitards improves its ability to maintain water infiltrating in the form of recharge.

5.4.3.1.4 Sannine Aquifer (C_4)

The Sannine formation is considered one of the most important aquifers in the Cretaceous sequence. It is a karstic aquifer characterized by significant amount of groundwater flowing in channels, faults, and fractures. However, it is worth noting that the Sannine aquifer has a relatively low thickness of maximum 200m in the study area as noted in the cross section (Appendix A). The Sannine aquifer is composed of a recharge zone in elevated areas, while the discharge zone is located at lower altitudes at a boundary with the Hammana formation. According to the UNDP (1970) report, the infiltration coefficient of this aquifer reaches 40%.

Furthermore, the Sannine aquifer acts as a source for several types of karstic springs. Being underlain by the Hammana aquitard a karstic spring line has developed along its lower boundary. Those springs show discharges that typically increase rapidly during the winter season and decrease to almost dryness during the summer season. The Sannine aquifer is considered the major aquifer in the study area, covering approximately 60 % of the surface and underground features reveal the advanced karstic nature of this aquifer. These features include solution joint, solution pits, lapiaz, grooves, and sinkholes. Cavities in the rock are often filled with calcite and cave deposits. The thickness of the topsoil on this formation ranges from few centimeters up to few meters.

5.4.3.2 Aquicludes (Abeih and Hammana aquicludes; C_3 -C_{2b} Formation)

The Hammana and the Abeih Formations constitute aquicludes with poor hydraulic properties because of the low porosity, consequently the low hydraulic conductivity for argillaceous limestone, clays, and marls. Therefore, forming impermeable boundaries for the Sannine and Mdairej aquifers, which prohibit exchange of water between the different hydrostratigraphical units. According to the UNDP (1970) report, the infiltration coefficient of this aquifer does not exceed 10-15%.

5.4.3.3 Spring Survey

For the purpose of the hydrogeological study of the area, a spring survey was conducted by ELARD team. This survey revealed the presence of eight springs in both Jebaa and Mrousti. The locations of the identified springs are presented on the geological map (Appendix A). The discharge of the springs has been measured using a stopwatch and a bucket of 17.5 liters. Some springs discharge from the Chouf Sandstone such as Ain Et Tahta, Ain Abdallah (Photograph 5.11), and Ain El Ghebe (Photograph 5.12), which have very low discharge not exceeding 1 L/sec. The springs discharging from the Bikfaya Formation have greater yields. Other springs discharge from the Sannine Formation, such as Ain Jebaa Ech Chouf (Photograph 5.13) and Ain Mrousti (Photograph 5.14), with discharges that exceed 2 L/sec during summer.

Photograph 5.11. Ain Abdallah spring, a Seepage zone along the main road in Mrousti

Photograph 5.12. Ain El Ghebe on the road leading from Mrousti to Khraibeh

Photograph 5.13. Ain Jebaa ech Chouf spring in Jebaa next to the municipality

Photograph 5.14. Ain Mrousti in the Village

Table 5.1. Characteristics of surveyed springs

Spring name	Aquifer	X coordinate	Y coordinate	Z coordinate	Discharge (l/sec)*
Ain Abdallah	J6	142081	186977	1210	<1
Ain El Ghebe	J6	142334	187491	1250	<1
Ain Et Tahta	J6	142336	187620	1250	<1
Ain Mrousti	C3-C4	141852	187344	1230	2
Ain Abou Kharma	C3	139433	186535	790	-
Ain Jbaa Ech Chouf	C4	140254	186317	1070	2
Ain Ec Chaachouaa	J6	141608	185627	1260	-
Nabbaa Ouadi Ghabe	J6	141523	185704	1210	-

***Note that discharges of the springs were measured in June 2004**

5.4.4 Hydrogeological Site Setting (Jebaa / Mrousti)

The Mrousti wastewater plant proposed site is located south to Mrousti at the intersection of two intermittent rivers in the Eastern Flank of the Mansoura Valley. On the other hand, Jebaa Ech Chouf wastewater plant site is located on the southern flank of Ouadi Daas, north to Jebaa Village. Both sites are located on the Sannine formation, which is a highly permeable formation. This Formation, as described earlier, is characterized by its high secondary porosity causing ground water to flow mainly through fractures, joints and channels, which is a typical occurrence in karstic aquifers. Both sites are located downstream to most of the surveyed springs in present in the studied villages. However, advanced levels of wastewater treatment are imperative in order to protect the groundwater within the Sannine aquifer from potential contamination and consequently, the spring that are mainly originating further down stream at the level of the contact zone between the Sannine Formation and the less permeable Hammana Formation.

5.5. GEOLOGICAL SETTING OVER MOUKHTARA & BUTMEH

The geology of these two villages, including subsurface Stratigraphy and structure, was developed based on: 1) review of available maps and literature, 2) analysis of aerial photographs, and 3) geological surveys and site visits conducted by ELARD geologists. The result was the generation of a geological map at a scale of 1:10,000 covering the area of study, reaching approximately eight Km^2 and lying within grid coordinates 139 000 and 141 000 Easting, and 189 000 and 192 000 Northing. The map is included in Appendix A. Two geological cross-sections (AB; CD) were drawn to illustrate the subsurface Stratigraphy and structure, underneath the proposed site in Moukhtara.

5.5.1 Stratigraphy

There are mainly three formations outcropping in this study area. Theses formations are described in the following section

5.5.1.1 Cretaceous

5.5.1.1.1 The Mdairej formation (C_{2b})

This formation consists in a cliff extended along the two sides of El Barouk River valley. This cliff consists of hard grayish micritic massive limestone rich in calcite veins. This formation is approximately 50m thick (Geological Map, Appendix A).

5.5.1.1.2 The Hammana formation (C_3)

This formation outcrops mainly in El Moukhtara, part of Butmeh, Ain Qani villages. It is characterized by creamish to greenish marly limestone. Quartz geodes can be found along ephemeral streambeds. This formation is also highly fossileferous, as molded gastropods and fossilized oysters are frequently found. A distinctive yellowish limestone bed of 25m thickness, known as the Banc de Zummoffen is present in the middle of this formation. This formation has a thickness of approximately 200-300m in this area.

5.5.1.1.3 The Sannine formation (C_4)

The Sannine formation outcrops in mainly Butmeh, Rass el Arid area, and Khraibeh village. This formation consists in its lower levels of marly lmestone that grades into thin beds of gray limestone especially along streambeds in the valleys. In its upper part, this formation is composed of massive gray limestone. Mainly, the thickness of this formation in the area reaches approximately 600m. (Geological Map, Appendix A). Massive limestones and dolomites, above the green or grey marls of the Hammana Formation, characterize the lower limit of the Sannine Formation.

5.5.2 Structure

Formations in the study area are dipping slightly generally towards the west at angles that range between 05º and 10º. Structural disturbances mainly through faults have a slight influence on the bedding attitude in the study area.

Faults trending in an East-West or Northwest-Southeast direction appear to predominate over this area. Faults in the study area are normal faults with relatively small throw that can reach up to 40 m.

5.5.3 Hydrogeological Setting

There exist in the study area two main aquifers. The Mdairej aquifer underlain by the Abeih aquiclude, and the Sannine aquiferous Formation underlain by the Hammana aquiclude.

5.5.3.1 Aquifers and Aquicludes

The two important aquifers present in the study area: the Sannine karstic aquifer, the Mdairej karstic aquifer, along with one main Hammana aquiclude.

5.5.3.2 Spring Survey

This survey revealed the presence of eight springs. The locations of the identified springs are presented on the geological and topographical maps (Appendix A&B). The springs with significant discharges exceeding 20 l/sec were encountered at the boundary between the Sannine and Hammana formation. All the water incoming from the recharge zone in the Sannine aquifer discharges at the impermeable boundary between the Hammana aquiclude and the Sannine aquifer. The most important springs in this area are, Ain el Machqir (Photograph 5.15) and Nabaa Mershed (Photograph 5.16). As for springs originating from the Sannine formation, they discharge at the marly section of the Sannine formation, especially for Ain El Aadass, and Ain El Mrah, which discharges decrease significantly in the summer time. The surveyed springs characteristics are shown in Table 5.2. Most springs with low yields are used locally by surrounding houses for drinking and domestic purposes, whereas some other springs are not used at all for these purposes but are still used for irrigation.

Photograph 5.15. Ain Mouchqir in Khraibeh, located on the boundary between Sannine and Hammana formation

Table 5.2. Characteristics of surveyed springs

Spring name	aquifer	X coordinate	Y coordinate	Z coordinate	Discharge (l/sec)
Yanbih (2Springs)	C4	139300	191420	900	-
Namless (2 Springs)	C3	138920	191590	740	<1
Nabaa Mershed	C3-C4	139949	190926	770	>20
Ain Moushqir	Boundary C3-C4	140600	190200	880	>20
Ain El Aadas	C4	141453	189559	1060	Dried
Ain Mrah	C3-C4	140838	189014	1070	1

5.5.4 Hydrogeological Site Setting (Moukhtara Site)

The wastewater plant site is located on the Western flank of Moukhtara on the Hammana Formation. This aquiclude is characterized by its relative low permeability and poor hydraulic properties because of the low porosity, consequently the low hydraulic conductivity for argillaceous limestone, clays, and marls. Therefore, forming impermeable boundaries for the Sannine and Mdairej aquifers, which prohibit exchange of water between the different hydrostratigraphical units (Appendix A presents the geological map of the location along with Geological cross sections of the area). The site is located downstream to the identified springs in the area, Ain Mershed and Ain Moushqir Springs. Therefore, the secondary treated effluent can be discharged directly in the Barouk River through an extended pipe from the treatment plant.

5.5.5 Hydrological Setting of the Study Area

One major perennial river the Barouk River passes through the study area. The Barouk River and its tributaries dominate the Eastern section of the Higher Shouf.

5.5.5.1 The Barouk River

The Barouk River is fed primarily by the Barouk spring that is situated at about 10 km outside the area northeast of Aammatour village. Flow measurements previously conducted at that spring indicate that its flow varies between 0.3 and 2.8 m^3/s, at dry and wet seasons, respectively (Guerre, 1969; Edgell, 1997). A hydrograph of this spring is represented in Figure 5.5 showing the average discharge measured between 1945 and 1969 (UNDP, 1970). The largest discharge is approximately 2.14 m^3/s and the lowest is approximately 0.34 m^3/s. This range could be representative of the flow of the surface water close to the source of the river. Further, down stream from the Barouk River, along the Awali section, a gauging station was positioned in Marj Bisri where records of discharge rate are presented as Figure 5.6.

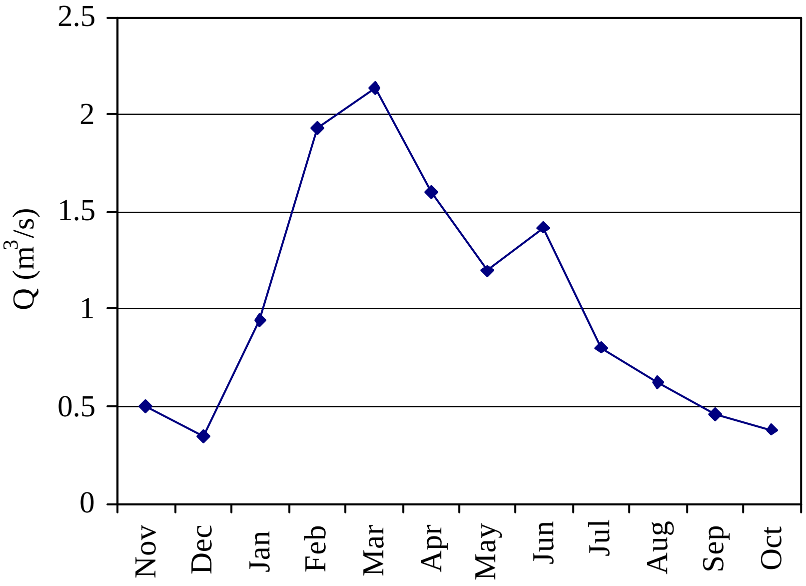


Figure 5.5. Hydrograph of Barouk Spring (1945 –1969)

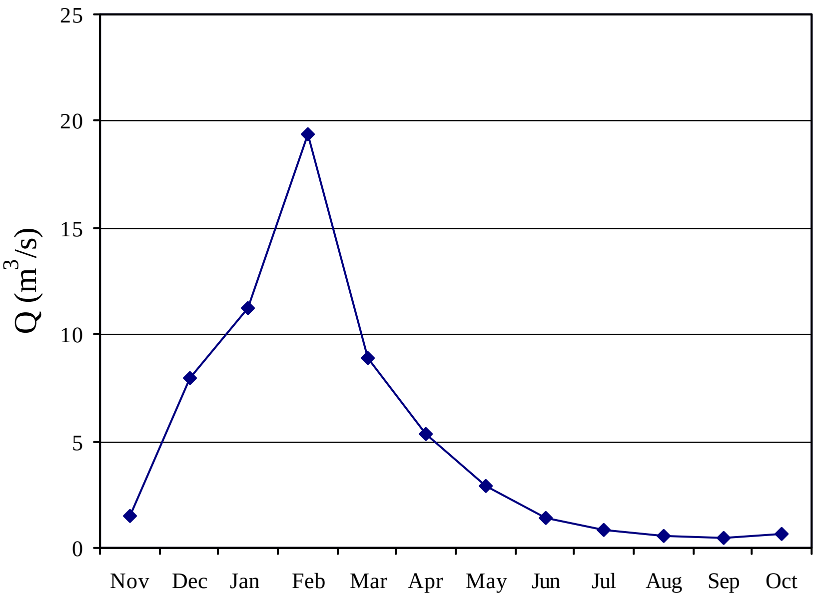


Figure 5.6. Hydrograph (1929-1955) of the Awali River on the Marj Bisri Station (UNDP, 1970)

5.6. WATER QUALITY

5.6.1 Spring Analysis

The main supplier of potable water in the area is the potable water well in Mrousti distributing water to most of the villages of Higher Shouf. A well is located at the Eastern outskirts of Maasser El Shouf used as source of potable water for that village. In Aammatour, El Arish spring is one of the major springs in that specific village and is used to supply drinking water to households but previous analysis of the spring showed contamination evidence. Therefore, local springs are being harnessed just for irrigation. It was observed that some of the local populations, however, do use spring water for domestic choirs. Table 5.3 presents analytical results of water samples collected from selected springs in the area of the respective villages. (Photograph 5.16) shows the sampling process on the Ain Mourchid spring. Table 5.4 presents analytical results of collected effluent from Baadaran wastewater treatment plant, using an EAAS system. The low BOD_5 value is the result of the extended aeration process, however; the relatively high value for the fecal Coliform can be correlated to the fact that during the summer season the chlorination is stopped or reduced since the effluent might be used for irrigation purposes. It is important to note that sewerage related contamination is detected in springs hydraulically down gradient of populated areas located on the recharge zone (that is of a Karstic nature) and/or located directly over the designated spring , in the like of the water samples from springs in Moukhtara, Aammatour, Baadaran, and Ain Qani.

The laboratory analytical reports of water samples collected from springs and rivers and analyzed during this study are included in Appendix B along with a Topographic Map indicating the sampling locations of the Barouk River and springs of the area.

Table 5.3. Laboratory Analytical Results of Five springs in Higher Shouf Municipalities Union (Samples Collected on 09/09/2003)

Sample ID	*Spring name / location*	*Faecal Coliform (CFU/100 ml)*	*Biochemical Oxygen Demand (mg/l)*
1	Ain el Arish (Aammatour)	5	<2
2	Ain Mourchid (Moukhtara)	10	<2
3	Ain el Fokor (Aammatour)	295	<2
4	Ain el Sayfiyeh (Baadaran)	5	<2
5	Ain Haret Jandal	0	<2
6	Maximum Allowable Levels *	0	5

* Drinking Water Standards per Ministerial Decision 52/1

Photograph 5.16. Sampling at Ain-Mourchid location

Table 5.4. Analytical results of collected effluent from Baadaran treatment plant

Sample ID	*Spring name / location*	*Faecal Coliform (CFU/100 ml)*	*Biochemical Oxygen Demand (mgO2/l)*
1	Effluent (Baadaran Plant)	1045**	<2
2	Allowable Levels *	2000	25

* NATIONAL STANDARDS FOR ENVIRONMENTAL QUALITY
** CFU/10ml

5.6.2 Barouk River Analysis

The Barouk River which bounds the villages of Higher Shouf as well as El Souwaijani villages was sampled at 3 random locations in order to measure the level of contamination or pollution due to the uncontrolled raw sewage discharges into that river. Table 5.5 presents analytical results of water samples collected from the Barouk River. The samples were collected at three different locations along the study area (Topographic Map Appendix B):

Location 1: The outskirts of Butmeh village.

Location 2: Southern boundaries of the study area.

Location 3: Marj Bisri Area

According to a general quality assessment of rivers and canals presented in Table 5.6, the concerned river could be classified as of a grade A. Therefore, water quality in Barouk River is considered good, since there is no major industrial wastewater discharge in the area. However, this type of chemical grading does not take into consideration the bacteriological criteria of the water. It is then conclusive that the main cause of Barouk river degradation is the uncontrolled raw sewage discharged upstream of the sample collection locations.

Table 5.5. Laboratory Analytical Results of three samples collected from random locations over the Barouk River

Sample Location	*Feceal Coliform (CFU/100ml)*	*Biochemical Oxygen Demand (mg/l)*	*Ammonia (mg N/l)*
Location 1	510	<2	<0.01
Location 2	23	<2	<0.01
Location 3	22	<2	0.01

Table 5.6. Chemical grading for Rivers and Canals. (Thames river-Standards 2000)

Water Quality	*Grade*	*Dissolved Oxygen (% saturation)*	*Biochemical Oxygen Demand (mg/l)*	*Ammonia (mg N/l)*
Good	A	80	2.5	0.25
	B	70	4	0.6
Fair	C	60	6	1.3
	D	50	8	2.5
Poor	E	20	15	9.0
Bad	F*			

*Quality which does not meet the requirements of grade E in respect of one or more determinates.

5.7. ECOLOGICAL CONTEXT (BIODIVERSITY)

Ecologically, the proposed locations are not in an area of special concern, such as areas designated as having national or international importance (e.g. world heritages, wetlands, biosphere reserve, wildlife refuge, or protected areas). In General, the projects will not lead to the extinction of endangered and endemic species, critical ecosystems, and habitats.

5.7.1 Ecological Context in Mrousti

The proposed site in Mrousti is situated in the Eu-mediterranean zone. The site extends over abandoned terraces that are heavily degraded due to grazing activities or other disturbances. The vegetation community is a degraded garrigue indicated by the relative high density of *Sarcopoterium* spinosum (Photograph 5.17). Sparse shrubs and grasses were identified such as *Spartium* junceum and *Calycotome* villosa (Photograph 5.18 and Photograph

5.19), along with some flowering species and spiny vegetation such as *Anthemis* rigida, *Astragalus* alopecuroides, *Centaurea* calcitrapa, *Helichrysum* sanguineum, *Inula* Montana, *Linum* pubescens, *Phlomis* fruticosa, *Putoria* calabrica, *Thymus* Spp. Consequently, the project is proposed on highly degraded and disturbed area where the habitat have been destroyed and / or removed. Hence, the site is suitable for any construction and operation works and this will not lead to significant impacts on biodiversity.

Photograph 5.17. *Sarcopoterium* spinosum and *Centaurea* calcitrapa

Photograph 5.18. *Spartium* junceum with its typical bright yellow flowers

Photograph 5.19. Calycotome villosa

***Anthemis* rigida**

***Astragalus* alopecuroides**

***Helichrysum* sanguineum**

***Inula* montana**

***Linum* pubescens**

***Phlomis* fruticosa**

Putoria **calabrica**

Thymus **spp.**

Photograph 5.20. Identified flora in Mrousti site

5.7.2 Ecological Context in Jebaa

This site area is situated in the Eu-mediterranean zone where a dominating *Quercus* community is present covering the edges of the proposed site. However, the site is proposed on a previously reclaimed part of the ecosystem, where the developed community is replaced by a terrace intended for agricultural activity. The *Quercus* sp. trees, shrubs and grasses are present on the edges of the site (Photograph 5.21).

Photograph 5.21. *Quercus* sp. community and shrubs surrounding the site. Photograph taken within the site

A variety of shrubs and grasses grow within this community such as *Spartium* junceum and *Calycotome* villosa (Photograph 5.22). The identified plant site is located within this community however, the previous agricultural activity on these terraces rendered the site area bare, but since the location is currently neglected, it is being colonized by a variety of grasses and shrubs.

Photograph 5.22. *Spartium* spp, *Quercus* spp. community around the site

5.7.3 Ecological Context in Moukhtara Site

The proposed site is located on an old neglected Olive orchard where the initially planted olive orchard is being colonized by a variety of trees and shrubs such as *Quercus* spp. community and other tree varieties. The site is then proposed in an agricultural ecosystem where the developed orchard is becoming degraded replaced by a community of native trees and shrubs (Photograph 5.23).

Photograph 5.23. Regenerating *Quercus* sp. community and olive orchards in the proposed site

A wide variety of shrubs and grasses grow within the orchard, this shows that the orchard is completely neglected since no plowing or irrigation activity has been performed. Furthermore, the olive trees are suffering from extensive damage due to neglect and disease infestations along with natural competion with regenerating native shrubs and trees (Photograph 5.24).

Photograph 5.24. Olive tree competing with the regenerating native shrubs and trees

5.8. INFRASTRUCTURE STATUS

Internal sewage network infrastructure is not present yet, therefore, PM along with the contribution of the various municipalities will finance the implementation the main sewage network connection to the plant along with the local community contribution. Hence, the municipality will complete the task of hooking the village's households to the main network by implementing the secondary network ensuring that all the generated sewage in the villages will reach the treatment plants.

Infrastructure within the towns is mainly limited to road network, telephone, electricity, and water supply. The supply of water was elaborated on in the hydrological section (section 5.5.3). Moreover, a local solid waste management system in the area does not exist and private companies manage solid wastes. Since mid 1997, the municipal solid waste is being disposed off in roadside containers/dumpsters that is managed and hauled off by Sukleen, the solid waste collection company operating out of Beirut. Moreover, the union of Higher Shouf

Municipalities is currently in the process of selecting a contractor to implement Solid Waste treatment plant that will serve all the villages in the area.

Wastewater treatment facilities are being currently constructed in the villages of Maasser el Shouf, Aammatour, Niha-Bater, and Khraibeh. Domestic sewage is however currently generally disposed of into "unregulated" septic tanks, or discharged directly onto open grounds. The construction of sewage networks is planned and will be implemented prior to the construction of the plant.

5.9. SOCIO-ECONOMIC STATUS

Socio-economic information about the various villages was obtained during informal meetings with Mayor and municipal council members during the field visits and through the filling of specifically prepared questionnaires (Appendix G). Table 5.7 presents some socio-economic information relevant to this study

Local inhabitants are mainly members of the active population (between 20 and 50 years old); the average age all over the surveyed villages is around 40 years. The economy in most municipalities of the area is mainly driven by public and private sector employments. Trade and services are also prevalent. Money sent by expatriates (people from the towns living abroad) is a main driver of the local economies as well. Tourism is very limited. Industry is present mainly in the form of small-varied industries like welding, carpentry in the area.

Average household income within the Union amounts to less than six million Lebanese pounds annually (or around 500,000 Lebanese pounds monthly).

Table 5.7. Socio-Economic Information (as given by Municipalities and Union)

Municipality	***Population*** Year-round/ Seasonal	***Priority for the Community***	***Economy Driver***	***Health & Educational Services***	***Farms & Farming***	***Gas Stations*** ***Lube Oil Service Car Mechanics***	Industry
El Moukhtara	1000 3000	Sewage network, solid waste collection, wastewater treatment plant	Agriculture (20%), Marketing (30%), Industry (10%), Employed (40%), Retired (10%)	1 school	Olives and fruits	None	None
Butmeh	800 1650	Wastewater treatment, solid waste management, water supply for agriculture	Agriculture (25%), Services (25%). Employed (25%)	None	Olives & fruits	1 Gas station	Steel industry, Aluminum, carpentry, gyps, carpentry
Mrousti	1200 1900	Sewage network and wastewater treatment	Agriculture (50%), Industry (15%), Services (15%), other (20%)	1 clinic (under construction) 1 governmental school	Not specified	1 Mechanics 1 Electrical 1 Lube oil services 1 Gas station (under construction)	Small industries 1 car mechanic 1 carpentry
Jebaa El-Shouf	1000 2000	Sewage network and wastewater treatment, solid waste management	Agriculture (60%), employed (20%), unemployed (20%)	1 clinic 1 governmental school (closed)	Fruits, Apples, cherry, olives, vegetables	None	None

6. IMPACT IDENTIFICATION AND ANALYSIS

On-site and off-site impacts can be induced during the construction of the plant, and later during its operation. On-site impacts result from construction activities carried out within the construction site. The impacts of off-site work result from activities carried out outside the construction site yet are directly related to the project. In the case of wastewater treatment plants, the main potential receptors are soil, surface, and ground water bodies. Identification of potential impacts is facilitated by the use of a matrix that shows the main activities at the wastewater treatment plant, the major perturbation factors, and the environmental media affected (Table 6.1). The extent of impacts depends primarily on the effluents management practices that would be adopted during plant operation.

6.1. IMPACTS ON WATER RESOURCES

6.1.1 Impacts during Construction

No major on-site impacts on water resources are anticipated during the construction phase of these plants. Care should however be exercised when handling fuel and oil (hydraulic, transmission, engine, etc.) to power and maintain the different equipment on site. Measures should be taken to avoid spillage of such material to the ground, as these contaminants would eventually reach the groundwater. Dumping excavated and construction material into nearby watercourses should be prohibited. Additionally, all earth-moving and other equipment should be in good working condition and well maintained (no leaks).

Off-site impacts on water resources may occur from the reckless disposal of domestic as well as industrial wastes, typically liquid and solid, generated form the residential units, offices, and equipment and vehicles maintenance units at the contractor's constructions site. Where proper waste segregation and disposal is practiced, the likelihood of these impacts to occur will be negligible, if not nil.

Table 6.1. Impact Identification Matrix

Phase	***Activities***								
Construction	Earth moving			√					√
	Excavation							√	√
	Truck movement		√					√	
	Erection							√	
Operation	Sewage conveyance	√							
	Preliminary Treatment	√		√	√				
	Secondary Treatment		√					√	
	Sedimentation			√					
	Sludge holding			√	√				
	Sludge return							√	
	Sludge dewatering							√	
	Disinfection						√		
	Effluent disposal					√	√		
	Sludge disposal			√	√	√	√		
	Perturbation factor	Sewage	Gas Emission	Solid waste	Odors	Heavy metals	Chemicals	Noise	Dust
	Environmental Media								
	River					√	√		
	Ground water	√		√		√	√		
	Agricultural soil					√	√		
	Nuisance		√	√	√			√	√
	Air quality		√						√
	Biodiversity		√		√	√	√	√	√

6.1.2 Impacts during Operation

During operation, the main activities that would affect the natural resources are the effluent management practices (section 4.5). Proper management of both the treated wastewater and the generated sludge is essential. Less commonly, flooding of the wastewater plant as well as leakage form the treatment basins can threaten groundwater resources. These should be avoided by adopting proper engineering codes and adequate preventive measures (Appendix J).

In general, secondary wastewater treatment, and specifically extended aeration activated sludge treatment systems, produces a highly treated and well-nitrified effluent that usually meets secondary effluent quality standards. In addition, in designs where advanced treatment is incorporated, such as the case forecasted Mrousti plant and Jebaa plant, BOD, TSS, nutrients levels, and bacterial population in the discharged effluent will be significantly suppressed. Thus, the proposed facilities discharge effluent quality is expected to meet the Environmental Limit Values (ELV) for wastewater to be discharged into surface waters, as specified by Ministerial Decision 8/1/2001. These measures will minimize or even nullify the negative impacts of the treatment plants on the environment. The effluent can as well be safely used for irrigation translating into a "positive" impact. However, such practice is not used as an effluent management option because this specific area has relatively considerable amounts of fresh water.

Therefore, treated effluent will be discharged in winter channels in the case of Mrousti and Jebaa plants (Advanced Treatment) and in a perennial river in the case of Moukhtara plant (Secondary Treatment). Then, the discharged effluent from the intended treatment plant in Moukhtara will be directly discharged into the perennial Barouk River. This practice will eliminate the negative impacts of uncontrolled discharge of raw sewage into the river. The intended treatment plants in Mrousti and Jebaa will discharge their treated effluents into the nearby winter channels that will consequently reach the Barouk River. Therefore, stricter ELV were subjected in order minimize the impact of infiltration of treated effluents into the ground water since the geological formation present in this area is relatively permeable. Table 4.18 indicates that very stringent effluent quality levels can be achieved with the proposed advanced wastewater treatment processes in Jebaa and Mrousti.

Nevertheless, for the three plants, in case of malfunction or improper operation, which would lead to insufficient levels of treatment, surface and groundwater would be at risk. This is why a stringent environmental management plan is proposed in the next section to minimize the likelihood of such events to occur. In particular, the selection of the main technology (EAAS) was made having in mind the need to select a proven technology with minimum risks of malfunction or plant breakdown.

Screenings, grit, and stable sludge generated from the wastewater treatment process will be properly managed to avert additional potential impacts on water resources. Therefore, the generated sludge from these treatment plants will be sent to the Solid Waste treatment plant in Kahlouniyeh to be co-composted along with the organic fraction of the incoming solid waste.

6.2. IMPACTS ON SOIL

6.2.1 Impacts during Construction

The total volume of soil and rock that would be excavated during plant construction is relatively small and thus should not lead to major erosion problems and impacts on soils.

Soil pollution from on-site as well as off-site works may occur by the intentional or accidental leakage of used chemicals, fuel, or oil products (from equipment and vehicles) on construction sites. Such practices should be strictly avoided and utmost precautions and workmanship performance should be adopted for the disposal of such hazardous products.

6.2.2 Impacts during Operation

The main concern during operation of the plant is related to soil quality rather than soil quantity, and is primarily attributed to generated sludge management. Generated sludge from wastewater treatment plants is usually used as soil fertilizer due to its relatively high nutrients content (whether used on site or off-site). However, if sludge application is not properly conducted, it can cause damage to soil fertility by breaking the C/N ratios and/or creating an imbalance in nutrient levels, possibly pollute the soil, and eventually reach the groundwater. Proper soil application depends not only on the sludge quality, but also on the soil physical and chemical properties, which would dictate whether the soil is suitable for receiving such material. In addition, even if the soil is suitable, sludge application should not exceed a certain maximum application rate. These measures are further elaborated in Appendix E.

Furthermore, since Co-composting of generated stable and dried sludge will be practiced in this area the compost produced from this process will be monitored regularly and frequently.

6.3. IMPACTS ON HUMAN AMENITY

Human amenity is defined inhere as general comfort of persons that could eventually be disturbed by factors such as dust, noise, and odors.

6.3.1 Impacts during Construction

The main impacts on human amenity during plant construction are related to dust and noise generation. An increase in ambient particulate matter may be observed primarily during the excavation activities. However, given the fact that excavation will last for a limited period, the impacts from potential dust generation will probably not be significant. On the other hand, appreciable increases in noise levels may be expected during excavation and erection of the plant. The impacts of noise from excavation and associated truck movements are however limited to construction phase.

6.3.2 Impacts during Operation

The main amenity impacts during plant operation are related to noise and odors. Noise may be generated mainly from the blowers and generator operation. However, adequate noise reduction/suppression measures are undertaken, the generated noise will not significantly affect human amenity and especially that the entire plants site are selected in relatively remote and down gradient areas (refer to appendices for Tender Document).

Odors emitted at a wastewater treatment works may easily reach the local inhabitants; especially that prevalent wind direction in valleys is towards the residential areas. Inlet works, grit channels, screening and grit handling, aeration tanks, and sludge holding and dewatering units are the main sources of odor at the wastewater treatment facility. However, in many instances, odors will be reduced or prevented through adequate WWTPs designs, normal housekeeping, improved operation, and maintenance design procedures.

Therefore, odors may be primarily produced from the sludge drying beds early in the process. Then the stabilized and dried sludge on-site will be hauled off to be incorporated in the composting process of the organic fraction of the municipal solid waste in the area; therefore, sludge management (proper storage, handling and off-site transportation and disposal/ co-composting in this case) should be properly managed. Proper handling procedures are presented in Section 7 and should be abided by in order to ensure an extended life span for the plant and it sustainability.

6.4. IMPACTS ON PUBLIC AND OCCUPATIONAL SAFETY

6.4.1 Impacts during Construction

In any civil works, public as well as construction staff safety risks can arise from various constructions activities such as deep excavations, operation, and movement of heavy equipment and vehicles, storage of hazardous materials, disturbance of traffic, and exposure of workers to running sewers. Because of the short duration and non-complexity of the construction phase, such activities are controlled and consequently the associated risks are minimal. Proper supervision, high workmanship performance, and provision of adequate safety measures will suppress the likelihood of such impacts on public and occupational safety.

6.4.2 Impacts during Operation

During the operational phase of the plant, occupational safety is at a higher risk than public safety. Fortunately, various mitigation measures can be easily adopted to minimize occupational hazards. Such measures are detailed in section 7 and should be stringently considered.

6.5. IMPACTS ON BIODIVERSITY

6.5.1 Impacts during Construction

The proposed sites are located on a disturbed, degraded, or neglected land therefore the proposed projects will not lead to significant negative impacts on biodiversity, especially that the excavation process will just target a relatively small parcel and the risks of loss of species is minimal. However, throughout construction efforts will be set forth to conserve present trees or even relocate trees within the site to be set as wind and visual break. Potential and general negative impacts affecting biodiversity during projects construction are summarized in Table 6.2. The main construction activities having negative results on the biodiversity are earth-moving activities, erection of the plant, and construction waste material disposal and effluent discharges. However, the potential negative impacts are not considered very significant since each project only affects a degraded or neglected portion of the ecosystem.

Table 6.2. Potential Negative Impacts on Biodiversity

Impact	**Cause**
Habitat loss or destruction	Construction works
Altered abiotic/site factors	Soil compaction, erosion
Mortality of individuals	Destruction of site vegetation
Loss of individuals through emigration	Following disturbance or loss of habitat
Habitat fragmentation	Habitat removal and/or introduction of barriers like roads
Disturbance	Due to construction noise, traffic, or presence of people
Altered species composition	Changes in abiotic conditions, habitats…
Vegetation loss	Soil contamination due to disposal of oils and hazardous material

On the other hand, the project will include an ecosystem rehabilitation plan to regenerate and protect the native species community present around the sites therefore leading to great positive impacts on the biodiversity level.

6.5.2 Impacts during Operation

With proper management of effluent material as stated earlier, negative impacts on biodiversity during operation of the plants should be minimal. On the contrary, the projects could lead to positive environmental impacts on the biodiversity level if plans are developed to protect surrounding areas. Inclusion of original species in the proposed landscape plan could be adopted to alleviate visual impacts and compensate loss of communities, if any. The surrounding communities of various species should be preserved and even incorporated in case of loss, in order to act as a windbreak and eventually reduce the dispersion of odors around the plants. Such measures can act as well in blending the plants in the surrounding environment.

6.6. IMPACTS ON HUMAN HEALTH AND SANITATION

The current lack of proper solid and liquid waste management was proven to have a surely negative impact on human health and the environment (Refer to section 5.6). Current and historical dumping of wastes, whether in open dumps or in sinkholes, is directly polluting the environment and water resources of the area, and is furnishing breeding habitats for rodents and diseases to flourish. Such impacts will be mitigated by the deployment of a proper sewer collection system and by the treatment of the collected sewage. Of utmost importance is the coverage of the collection systems to the whole villages. Wherever a property cannot deliver to the system its sewage by gravity drainage, proper measures in the form of secure septic systems or pumping stations should be installed.

As a whole, the projects would lead to POSITIVE impacts with respect to human health. Improvements in health conditions are likely to occur as the result of improvements in surface, groundwater, and spring water quality as well as sanitation conditions.

6.7. SOCIOECONOMIC IMPACTS

Additional POSITIVE impacts would be observed at the socioeconomic and agriculture levels. The proposed projects will create certain job opportunities for skilled and unskilled labor. Moreover, if the treated effluent is to be reused for irrigation (however, not likely), the projects may have long-term positive impacts on agriculture. Moreover, the co-composted sludge in the Solid Waste Composting plant can be used as well in agricultural, municipal landscape or silviculture (as portrayed before) fertilization practices, therefore alleviating organic or synthetic fertilizer costs on farmers. With careful monitoring of Compost or sludge quality, the sludge would be of a benefit and ensure a quick acceptance of this byproduct in the market or would be used in the rehabilitation process of quarries.

6.8. IMPACTS ON ARCHAEOLOGICAL, TOURISTIC AND CULTURAL SITES

Although not applicable to any proposed location, the impacts of the deployment of wastewater treatment plants on archaeological, Touristic and cultural sites is positive, considering this specific area has high tourism and Eco-tourism capabilities. This is particularly important since a major nature reserve (Arz El Shouf reserve) is located in the area and several ecotourism activities are being initiated by NGOs such as the SRI (Stanford Research institute) project, funded by USAID. Furthermore, each plant by itself or the effluent generated at these plants will have no negative effect on the reserve since **the reserve is located up gradient to the plants** at a distance of 7 km from Moukhtara plant site, 7.5 km from Mrousti plant site, and 8.5 km from Jebaa plant site.

7. ENVIROMENTAL MANAGEMENT PLAN

7.1. OBJECTIVES OF THE ENVIRONMENTAL MANAGEMENT PLAN

The proper implementation of a comprehensive environmental management plan (EMP) will ensure that the proposed wastewater treatment plants meet regulatory and operational performance (technical) criteria. Environmental management/monitoring is essential for ensuring that identified impacts are maintained within the allowable levels, unanticipated impacts are mitigated at an early stage (before they become a problem), and the expected project benefits are realized. Thus, the aim of an EMP is to assist in the systematic and prompt recognition of problems and the effective actions to correct them, and ultimately good environmental performance is achieved. A good understanding of environmental priorities and policies, proper management of the plants (at the municipality and the Union levels), knowledge of regulatory requirements and keeping up-to-date operational information are basic to good environmental performance.

7.2. MITIGATION MEASURES

7.2.1 Defining Mitigation

In the Environmental Impact Assessment context, mitigation refers to the set of measures taken to eliminate, reduce, or remedy potential undesirable effects resulting from the proposed actions, here the municipal wastewater treatment plants. Mitigation should be typically considered in all the developmental stages of the facilities, namely, the site selection process, as well as the design, construction, and operation phases. Once set, tender documents should clearly describe mitigation measures and workmanship to be adopted by the contractors or operators.

7.2.2 Mitigating Adverse Project Impacts

As identified earlier, potential adverse impacts of the proposed wastewater treatment plants may include dust emissions, odor and aerosol generation, noise generation, degradation of natural resources, production of residuals, public health hazards, and adverse aesthetic impacts. Proposed mitigation measures for the above-mentioned adverse impacts are discussed in the following paragraphs. Table 7.3 summarizes such mitigation measures, their monitoring for actions affecting environmental resources and human amenity. Such measures should be set as primary conditions on the contractor, the supervising engineers, the WWTP administration, and operating staff in order to assure a proper management of the plant as well as the implementation of the Environmental Management Plan (EMP).

7.2.3 Mitigating Degradation of Receiving Water Quality

In general, secondary wastewater treatment, and specifically extended aeration activated sludge treatment systems produce a highly treated and well-nitrified effluent that meets secondary effluent quality standards. Advanced treatment levels when employed (case of Mrousti and Jebaa), further suppresses BOD, TSS, Nutrient content and bacterial population in the discharged effluent (Table 4.18). Thus, the proposed facilities' discharge effluent quality will meet the Environmental Limit Values (ELV) for wastewater discharged into surface waters, as specified in the National Standards for Environmental Quality. When secondary effluent guidelines are met, the effluent can be safely used for irrigation (Appendix F). When the produced effluent volumes exceed water demand, the effluent can be safely discharged into nearby winter channels such as in Mrousti plant and in Jebaa plants where advanced treatment levels are subjected.

It is always essential that discharge points be downstream of vital springs however, in the case of Jebaa and Mrousti as stated earlier, since discharge point will be unwillingly located upstream, advanced levels of effluent treatment were recommended. The absence of nearby perennial streams, the geological setting of the area was thoroughly considered and studied before discharging the effluent on land or in the available intermittent stream.

To attain the expected safe effluent discharge, skilled and trained operator is necessary for proper process loading, optimization, control, and thus performance. Furthermore, the discharge of industrial wastewater and oil/grease into the treatment facility should be prohibited and illegal discharge controlled by the concerned authority. Operational upsets due to ambient temperature variations should be overcome by the provision of adequate preventive measures such as proper covers and thermal accessories. The implementation of training recommendations, maintenance plans, and process and effluent monitoring programs should be *mandatory*. Sufficient instrumentation and standby equipment (blowers, pumps, and electric generators) will be provided to ensure an uninterrupted and controlled operation, thus avoid inefficient process performance. Drains and bypasses will be designed for emergency cases.

For the Jebaa and Mrousti plants, it is recommended to construct the plants on an impermeable liner seal to prevent the leakage of untreated influent into the underlying karstic layer into the groundwater.

In situations where mandated treatment standards are not met, additional process control should be attained, further effluent treatment considered, or alternative effluent disposal schemes adopted, given the quality of effluent is acceptable for the proposed applications or discharge.

7.2.4 Mitigating Dust Emissions

Dust emissions from piles of soil or from any other material during earthwork, excavation, and transportation should be controlled by wetting surfaces, using temporary windbreaks, and covering truckloads. Piles and heaps of soil should not be left over by contractors after construction is completed. In addition, excavated sites should be covered with suitable solid material and vegetation growth induced after construction completion, no soil surface should be kept bare subject to erosion.

It is the responsibility of the Supervision Engineer to monitor for the mitigation of such impacts.

7.2.5 Mitigating Noise Pollution

Temporary noise pollution due to construction works should be controlled by proper maintenance of equipment and vehicles, and tuning of engines and mufflers. Construction works should be completed in as short a period as possible by assigning qualified engineers and supervisors. It is the responsibility of the Supervision Engineer to monitor for the mitigation of such impacts. Noise pollution during operation would be generated by mechanical equipment, namely pumps, air blowers, and sludge dewatering units (if present). Noise problems will be reduced to normally acceptable levels by incorporating low-noise equipment in the design and/or locating such mechanical equipment in properly acoustically lined buildings or enclosures. In the presence of adequate buffer zones between the facility and residential areas, the need for noise control measures is minimized. In this case, the plants sites are located at distances of at least 0.7 Km from the nearest household or institution in the concerned villages. Furthermore, dispersion of noise can be reduced by preserving or incorporating the surrounding native species of trees that will act as a wind and sound break.

7.2.6 Mitigating Obnoxious Odors

Odors emitted by the wastewater treatment works may be potential nuisance to the public. Inlet works, grit channels, screening and grit handling, aeration tanks, and sludge holding and dewatering units are the main sources of odor at the wastewater treatment facility. However, in many instances, odors can be reduced or prevented through normal housekeeping, improved operation, and maintenance design procedures. When kept clean, sludge transfer systems, such as conveyors, screw pumps, conduits, and finally sludge beds will not generate odors. The primary mitigation measure for odor control remains the proper siting of the facility, performed earlier during the site selection and considered as a major criterion in the process. The plant should then be located at a site where prevailing winds mostly blow away from nearby residential areas. In addition, adequate buffers from treatment units should be considered. As a guide, suggested minimum buffer distances from some treatment units are presented in Table 7.1. Furthermore, the selected technology based initially on simple and conventional *aeration* processes are not expected to emanate extensive amounts of foul smell that could only be generated in case of anaerobic processes or in case of bad operation of the plant. The sole component in the system that might generate odors is the sludge drying beds early in the drying process. However, the sludge generated from such type of systems is mainly stabilized through extensive aeration, recycling. Therefore, no biological activity will be present, consequently no anaerobic process will occur in the drying beds.

Table 7.1. Suggested minimum buffer distances from treatment units

Operation unit/process	Buffer distance (m)
Sedimentation tank	120
Aerated tank	150
Aerated lagoon	300
Sludge holding tank	300
Sludge thickening tank	300
Sludge drying beds (open)	150
Sludge drying beds (covered)	120
Sludge digester	150

Activated sludge tanks do not normally emit an objectionable odor when a dissolved oxygen level of $\geq$ 2 mg/L is maintained in the mixed liquor. Thus, it is essential to execute a regular program of maintenance to prevent the clogging of diffuser plates to maintain adequate dissolved oxygen levels in the aeration tanks, which in turn minimizes the chances for the production of odorous compounds. Regular cleaning of aeration tank walls and floors, washing weirs, and removing scum regularly, also helps in odor reduction.

Where odor emissions could lead to complaints, the provision of covers to the odor sources should be considered, especially for sludge holding tanks and sludge drying systems. To reduce odors from final settlement tanks and sludge holding tanks, logical operational solutions include increasing the pumping rate of the thickened sludge, monitoring a low sludge blanket level, and increasing the influent flow rate to the sludge-holding tank without losing thickening. Tank mixing during off-shifts will also minimize the release of trapped gas during the day. Occasional tank draining and filling it with chlorinated water further reduces odor problems. To reduce odors from dewatering units, pH adjustment or introduction of chemicals may be employed. An affordable measure to reduce partly odor problems can be storing produced residuals in closed containers and transporting them in enclosed container trucks. Flow regulating chambers, drainage valves, standby pumps, as well as electric standby generators should be provided to reduce the possibility of wastewater flooding within the wastewater treatment plant site, which results in possible generation of obnoxious smell. The presence of multiple aeration basins in the plant also reduces overflowing problems.

Proper landscaping around the facility along with the existing landscape may serve as a natural windbreaker and minimize potential odor dispersions. When odor becomes an evident public nuisance, synthetic windbreakers (e.g. walls) should be employed to maintain odor nuisance within each site.

7.2.7 Mitigating Aerosol Emissions

The process of aeration may result in the emission of sprays or aerosols. To limit such emissions, adequate feedboards should be considered, or suppression hoods, splash plates or deflectors be incorporated on the rotors, if employed. Moreover, the edge of the aeration basin can be raised 50-60 cm above water level to reduce aerosol emission.

7.2.8 Mitigating Impact on Biodiversity

Recommended mitigation measures to minimize or eliminate the impacts on the biodiversity at proposed locations, include:

- Avoid deforestation activities: plan the building sites and roads on areas void of trees within the site.
- Design a landscape plan that enhances the landscape esthetic value using local and native population flora.
- When detected, sensitive species or habitats should be conserved.
- All waste resulting from construction works, land reclamation, or any other activity should be collected, disposed properly in an allocated disposal site, and/or used onsite in the cut and fill process. Littering in the project area and surrounding areas should be prevented.

Table 7.2 presents additional mitigation measures specific to each location or site.

Table 7.2. Additional Mitigation of Impacts on Biodiversity Specific to the Location

Location	**Mitigation Measures (specific)**
Mrousti	Building the plant on the selected site would not lead to significant environmental impacts on the present biodiversity since it is degraded. Design a landscape plan that reintroduces species that were present in the old community of the area such as Quecus *sp*. or Pinus *sp*. and others. Act as a windbreak and odors break leading to a reduced dispersion of noise and odors, helping in blending the plant with the surrounding environment. Carefully design the access road rehabilitation to minimize removal of trees, especially old trees. Avoid removal of mature *Quercus* spp. trees present on the intended road that will lead to the site. Avoid alteration of abiotic factors

Location	Mitigation Measures (specific)
Jebaa	The plant on the selected site would not lead to significant environmental impacts on the present biodiversity. The plant will be built on an old agricultural terrace surrounded by Quercus sp. trees that will act as a natural visual barrier. No need for a landscape plan as long as the available natural environment is preserved during construction. These trees act as a windbreak and odors break leading to a reduced dispersion of noise and odors, helping in blending the plant with the surrounding environment. Carefully design the plant and access road rehabilitation to minimize removal of trees, especially old trees. Avoid removal of mature Quercus spp. trees present on the intended road that will lead to the site. Avoid alteration of abiotic factors
Moukhtara	The excavation of the site will definitely remove the regenerating variety of trees within the old olive orchard. However, this process will not cause extensive loss of species The landscape plan will integrate the old olive trees and other native trees present onsite that can be easily transplanted around the site. These trees act as a windbreak and odors break leading to a reduced dispersion of noise and odors, helping in blending the plant with the surrounding environment

7.2.9 Mitigating Impacts from Residual Storage, Handling, Transport, and Reuse/Disposal

The residuals resulting from extended aeration activated sludge treatment systems include screenings, grit, scum, and sludge. To reduce potential impacts of such residuals, proper handling, storage, transport, and disposal/reuse strategies should be adopted.

Screenings: When the plants are equipped with screens, these are to be cleaned regularly and screenings drained on a platform. Drained screenings should be collected in closed containers for ultimate transport and disposal at a nearby municipal solid waste disposal site. Hauling of screenings is to be carried by closed-top trucks.

Grit: In case of Grit removal device presence: Grit consisting of sand and gravel, from properly designed and operated gravity grit separators, is generally inert in nature, low in organic content, and relatively innocuous. Thus, the proper design and operation of grit chamber serves as the primary mitigation measure. Grit is to be washed daily and separated such that organic particles that are trapped with the grit will be recycled back into the flow stream. This will maintain odorless clean grit in open storage. The washed grit is then transported to an allocated municipal solid waste disposal site or it could be disposed on a nearby rubble land, if available.

Scum: Adequate scum collection and removal facilities are to be provided in the final settlement tanks of the extended aeration activated sludge system to prevent floating material and scum to be carried with the effluent and deteriorate its quality. Collected scum can be treated with the sludge.

Oil and grease should not pose a serious problem since their discharge into the wastewater treatment plant is prohibited to ensure high purification efficiency and avoid operational upsets. However, the safe incorporation of an interceptor tank to trap grease will reduce any chances encountering troublesome grease persistence in the system.

Sludge: Due to the long solids retention time (SRT) and the prevailing aerobic conditions in extended aeration activated sludge systems, the production of wasted sludge is somewhat reduced and the waste sludge is organically more stable. Thus, toxic and obnoxious gases are less expected to emanate. The proper design and operation of proposed sludge handling and treatment units will mitigate sludge-induced impacts. The dewatered sludge storage area should be bounded to contain any surplus liquids, which should be returned to the inlet works. Adequate storage capacities are to be provided on-site. Transport of sludge should be by top-covered trucks. Truck drivers should be instructed not to have the truck wheels come in contact with the sludge when loading, and not to overload to avoid spillage along travel roads. It is recommended to use the produced sludge for agricultural landscape fertilization programs, land reclamation etc; thus, agreements are to be set up with proper authorities or private individuals for sludge reuse. <u>Since the wastewater discharged into the plant is basically of domestic origin, the concentration of heavy toxic metals in the sludge is expected to be very low or even null.</u> Moreover, the sludge will be incorporated within the composting process of the SWTP intended for Higher-Shouf area.

Nitrification and denitrification are expected to occur in an extended aeration system, thus the impact of excess nitrates and even other nutrients on the soil and ground water will also be overcome, especially that some attenuation, natural filtration and nutrient adsorption will occur within the soil matrix.

Appropriate methods and proper management at the agricultural sites also have to be implemented to minimize adverse impacts due to sludge reuse. Farmers should not spread the sludge or compost onto land by hand as to avoid health risks as well as proper and specific guidelines should be implemented, incorporating the sludge or compost into the soil by mixing and adequately covering with soil. Protective clothing should also be worn. Sludge should not be applied to wet or frozen soils. Farmers should be well trained and informed to accept the issue of using sludge as organic fertilizer.

In the absence of adequate markets for sludge or co-compost reuse, alternative environmentally sound sludge management strategies should be considered. This may be proper landfilling, incineration, or use for land and quarries rehabilitation. However, in this case Co-composting will be practiced safely and will enhance the quality of compost produced within the SWTP of higher Shouf, hence its marketability.

7.2.10 Mitigating Adverse Aesthetic Impacts

To avoid possible visual impacts resulting from the existence of wastewater treatment facilities, the following steps are to be implemented:

- Maintaining cleanliness within each treatment plant (preventing spillovers, cleaning roads and ground, etc.).
- Appropriate landscaping of the plant grounds with planting of suitable trees, grass, and flowers.
- Fencing and screening the site with appropriate trees to obstruct the plant components from onlookers and area inhabitants. (All along with some noise reduction).
- Preserve the surrounding forest (if present) that will provide appropriate visual cover of the facility.
- Forecast for a reforestation plan around the site where effluent and sludge can be used respectively for irrigation and soil amendment.

7.2.11 Mitigating Public and Occupational Health Hazards

The likelihood of impacts on public and occupational safety can be significantly suppressed by the following mitigation measures:

- Restricting unattended public access to the wastewater treatment plants by proper fencing and guarding.
- Surrounding excavated locations with proper safety barriers and signs.
- Controlling movement of equipment and vehicles to and from the site, especially in the construction phase.
- Properly labeling and storing chemicals (Chlorine gas or powder), oils, and fuel to be used on-sites.
- Emphasizing safety education and training for system staff. Enforcing adherence to safety procedures.
- Providing appropriate safety equipment, fire protection measures, and monitoring instruments.
- Providing hand railing around all open treatment units, except where sidewalls extend ≥1.1 meters above ground level.
- Properly rating electrical installations and equipment and, where applicable, protecting them for use in flammable atmosphere.
- Providing sufficient lighting that should comply with zoning requirements.

As a conclusion, proper supervision, high workmanship performance, and provision of adequate safety measures will alleviate public and occupational risks.

Table 7.3. Mitigation Measures, Monitoring, and Estimated Costs for Actions Affecting Environmental Resources and Human Amenity

Action	*Potential impact*	*Mitigation measures*	*Monitoring of mitigation measures / responsibility*	*Estimated cost of mitigation (USD)*
A. During Construction				
Excavation and earth movement	• Dust emission	• Wetting excavated surfaces • Using temporary windbreaks • Covering truck loads	Supervision engineers	Required in tender/ Included within contract
	• Noise generation	• Restriction of working hours to daytime • Employing low noise equipment • Proper maintenance of equipment and vehicles, and tuning of engines and mufflers	Supervision engineers	Priced within contract
	• Erosion	• Proper resurfacing of exposed areas • Inducing vegetation growth	Supervision engineers	ditto
	• Disturbance to biodiversity	• Conservation of present trees and used as wind brakes and esthetic cover for the facility. • Inducing vegetation growth	Supervision engineers	ditto
Dumping of excavated and construction material into nearby watercourses	• Surface and groundwater pollution	• Prohibition of uncontrolled dumping. Disposal at appropriate locations • Education of workers on environmental protection	Supervision engineers	ditto
Discharge of wastes (chemicals, oils, lubricants, etc.) on-site	• Soil and water pollution	• Prohibition of uncontrolled discharge. Proper disposal of hazardous products • Education of workers on environmental protection	Supervision engineers	ditto
Storage of hazardous material, traffic deviation, deep excavation, movement of heavy vehicles, exposure to running sewers, etc.	• Hazards to public and occupational safety	• Proper supervision for high workmanship performance • Provision of adequate safety measures, and implementation of health and safety standards	Supervision engineers	ditto

B. During Design & Operation				
Inadequate process design and control	• Generation of obnoxious odors	• Improving operation and maintenance design procedures • Provision of covers where possible • Landscaping a proper natural windbreaker around the facility • Preservation of the Quercus spp trees around the plant site act as windbreaks.	Design engineers	ditto
		• Maintaining proper cleanliness and housekeeping • Transportation of odorous byproducts in enclosed container trucks • Diluting, masking or treatment of odorous emissions	WWTP administration and operating staff	
	• Impaired aesthetics	• Maintaining cleanliness around and within the plant • Proper fencing and landscaping • Preservation of the Quercus spp trees around the plant site.	WWTP administration and operating staff	ditto
	• Aerosol emissions	• Allowing adequate feedboards for aeration basins • Employing suppression hoods or splash deflectors on rotors	Design engineers	ditto
	• Noise generation	• Incorporating low-noise equipment • Locating mechanical equipment in proper acoustically-lined enclosures • Preservation of the Quercus spp trees around the plant site	Design engineers	ditto

	• Public & occupational hazards	• Restricting unattended public access • Providing adequate safety measures and monitoring equipment • Emphasizing safety education and training for system staff • Implementing health and safety standards	WWTP administration and operating staff	ditto
Inappropriate effluent management practices	• Pollution of effluent receiving water bodies	• Monitoring of effluent quality for surface water, groundwater, or marine discharge • Effluent discharge in accordance with MoE's ELV	MoE or MoEW	N/A
	• Contamination of crops and vegetables irrigated with effluent	• Monitoring the suitability of effluent for crop irrigation • Training farmers for the proper handling of effluent	MoE or MoA	N/A
Inappropriate screenings and grit management practices	• Soil and groundwater pollution at storage and disposal sites	• Proper washing, draining, and separating of screenings and grit • Hauling in closed-top trucks and disposal at an allocated municipal solid waste disposal site.	WWTP administration and operational staff	Operation and maintenance
Inappropriate sludge management practices	• Soil and groundwater pollution at sludge storage, disposal, or reuse sites	• Proper design and operation of sludge handling and treatment units • Provision of adequate storage areas and capacities on-site • Proper sludge transport by top-covered trucks • Monitoring of sludge quality prior to disposal or reuse • Training farmers for the proper handling and use of sludge at the agricultural sites	Design engineers and operational staff Design engineers WWTP administration and operation staff WWTP administration and operation staff Ministry of Agriculture or private companies	Operation and maintenance

7.3. ENVIRONMENTAL MONITORING PLAN

Two monitoring activities have to be initiated for the proposed wastewater treatment plant to ensure the environmental soundness of the project. The first is *compliance monitoring*, and the second is *impact detection monitoring*. Compliance monitoring provides for the control of wastewater treatment operational activities, while impact detection monitoring relates to detecting the impact of the operation on the environment. Together, the objective is to improve the quality and availability of data on the effectiveness of operation, equipment, and design measures and eventually on the protection of the environment.

7.3.1 Compliance Monitoring

In this context, compliance to the regulations set by the Ministry of Environment to limit air, water, and soil pollution shall be observed. Compliance monitoring requirements include *process control testing*, *process performance testing*, and *occupational health monitoring*. Compliance monitoring shall be the responsibility of each treatment plant administration (municipality and the Union), thus monitoring activities shall be budgeted for accordingly.

For effective compliance monitoring, the following shall be assured:

- Trained staff (plant operator, laboratory staff, maintenance team, etc.) and defined responsibilities
- Adequate analytical facility (ies), equipment, and materials, if possible.
- Authorized Standard Operating Protocols (SOPs) for representative sampling, laboratory analysis, and data analysis.
- Maintenance and calibration of monitoring equipment.
- Provision of safe storage and retention of records.

In the proposed wastewater treatment facility, qualified plant operators and laboratory staff should carry out process control and performance testing. The technical staff that would run the plants shall attend training programs to improve their qualifications and update their information. Both Contractors and Consultants would be involved in knowledge transfer to operators and management through regular assistance and specialized technical workshops.

For an extended aeration activated sludge system, a comprehensive list of process control parameters is presented in Table 7.4. It is noteworthy to mention that the wastewater treatment plants proprietors or operators should cooperate with the technology provider for a better approach in process control. This course of action is needed since a precise and adapted process control strategy translates into a better process performance, and thus compliance. Accurate process control is even more essential at the start-up phase of the activated sludge system to ensure a subsequent uniform operational phase.

Table 7.4. Process control parameters for an EAAS system

Sampling Location	*Analytical Parameter*	*Sample*	
		Type [1]	*Frequency*[2]
Plant influent [3]	Flow	In situ	D
	pH	In situ	D
Mixed liquor	Dissolved oxygen	In situ	D
	pH	In situ	D
	Temperature	In situ	D
	Total Suspended Solids	C	1/W
	Volatile Suspended Solids	C	1/W
Return activated sludge line	Flow	In situ	D
	Total Suspended Solids	C	1/M
Waste activated sludge line	Flow	In situ	D
	Total Suspended Solids	C	1/M
Final settlement tank effluent	Depth of blanket at mid tank	G	D
Post-chlorination	Residual chlorine	G	D
Sludge holding tank contents (if applicable)	pH	G	D
	Temperature	G	D
	Dissolved oxygen	G	D
	Alkalinity	G	1/W
Settled sludge in holding tank (if applicable)	Volatile acids	G	1/W
	pH	G	D
Sludge supernatant	Biochemical Oxygen Demand $_5$	C	1/W

[1] G: grab sample; C: composite sample (usually 24-hr composite grab samples every 8 hours, or 24-hr automatic sampler)
[2] D: daily, 1/W: once per week, 1/M: once per month Frequency may be adjusted as needed.
[3] Metals and organic compounds are less often determined, usually until a problem arises.

As for process performance monitoring, the list of recommended parameters is exhaustive; however, abidance is highly recommended especially during the first months of plant operation. Once a preliminary database is built, less frequent analysis can be performed, especially for the relatively invariable parameters. Table 7.5 summarizes the recommended process performance parameters for an extended aeration activated sludge system. Note that sampling frequencies are reduced at later stages of the operational phase. The plant operator may adjust the schedule of sampling in accordance to the operational characteristics of the system, and previous monitoring experience; however, utmost responsibility should be taken for uninterrupted compliance. Table 7.6 presents the recommended process performance parameters suggested in a draft law by the MoE.

Table 7.5. Process performance parameters for an EAAS system

Sampling Location	*Analytical Parameter*	*Sample Type* [1]	*Sampling Frequency*[2]		
			Early Operational Phase	*Advanced Operational Phase*	*Minimums sampling*
Plant influent [3]	Biochemical Oxygen Demand $_5$	C	1/M	1/2M	1/3M
	Total Suspended Solids	C	1/M	1/2M	1/3M
	Total Nitrogen	G	M [4]	1/2M [4]	1/3M
	Ammonia	G	M [4]	1/2M [4]	1/3M
Final settlement tank effluent	Biochemical Oxygen Demand $_5$	C	1/W	1/2W	M
	Total Suspended Solids	C	1/W	1/2W	M
	pH	In Situ	D	D	D
	Total Nitrogen	G	1/2W [4]	M [4]	1/2M
	Ammonia	G	1/2W [4]	M [4]	1/2M
	Nitrates	G	1/2W [4]	M [4]	1/2M
	Nitrites	G	1/2W [4]	M [4]	1/2M
Post-chlorination	Fecal coliforms	G	1/W	1/2W	M
Sludge holding tank contents (if applicable)	Nitrates	G	1/W	M	1/2M
	Ammonia	G	1/W	M	1/2M
	Total solids	C	1/W	1/2W	M
	Volatile solids	C	1/W	1/2W	M
Settled sludge in holding tank (if applicable)	Nitrates	G	1/W	M	1/2M
	Ammonia	G	1/W	M	1/2M
	Total solids	C	1/W	1/2W	M
	Volatile solids	C	1/W	1/2W	M

[1] G: grab sample; C: composite sample (usually 24-hr composite grab samples every 8 hours, or 24-hr automatic sampler)
[2] D: daily, 1/W: once per week, 1/2W: once per two weeks, M: monthly, 1/2M: once per two months, Frequency could be reduced if compliance violations are infrequent.
[3] Metals and organic compounds are less often determined, usually until a problem arises.
[4] Total nitrogen, ammonia, nitrates, and nitrites analyses can be excluded if influent concentrations for these parameters are within set standards, or if nitrogen removal is not within the capabilities of the employed wastewater treatment scheme.

Table 7.6. Process performance parameters suggested in a draft law set by the MoE.

Sampling Location	*Analytical Parameter*	*Sampling frequency*
Plant influent	Flow	Daily
	pH	Daily
Primary treatment Effluent	BOD_5	Daily
	pH	Daily
	Total Suspended Solids	Weekly
	Volatile Suspended Solids	Weekly
	Temperature	Daily
Secondary Treatment Effluent	BOD_5	Daily
	pH	Daily
	Total Suspended Solids	Once in 2Weeks (1/2 week)
	Volatile Suspended Solids	Once in 2Weeks (1/2 week)
	Temperature	Daily
	Total Nitrogen	Once in 2Weeks (1/2 week)
	Total Phosphorus	Once in 2Weeks (1/2 week)
Advanced Treatment Effluent / final effluent.	BOD_5	Daily
	pH	Daily
	Total Suspended Solids	Once in 2Weeks (1/2 week)
	Volatile Suspended Solids	Once in 2Weeks (1/2 week)
	Temperature	Daily
	Total Nitrogen	Once in 2Weeks (1/2 week)
	Total Phosphorus	Once in 2Weeks (1/2 week)
	Residual Chlorine	Daily

It is noteworthy to mention that initial comprehensive characterization of the wastewater to be treated is necessary for proper plant design, operation, and future monitoring. The tender documents presented for the bidders include plant influent characterization. Moreover, though analytical monitoring is essential, frequent observations of the aeration tanks and clarifier characteristics, such as aeration patterns, turbulence, foaming, and effluent clarity play an important part in performance monitoring. The frequency of monitoring can be reduced if it is necessary after constant recorded compliant values are obtained over a period of 2-3 years of normal operation.

After a successful plant start-up period, when a less thorough monitoring schedule can be implemented, monitoring efforts can be limited to regular checks (weekly or bi-weekly, as needed) of effluent quality for the following parameters:

- pH and temperature
- BOD_5 and COD
- Suspended solids
- Total Nitrogen
- Total Phosphorus
- Ammonia-nitrogen
- Nitrate–nitrogen
- Phosphate
- Coliform bacteria

However, in case of any sudden change in the trend of any parameter, it is imperative to reapply the advanced operational phase frequency in order to depict the anomaly.

The quality of dewatered sludge should also be checked before its incorporation in the co-composting process present in the Higher Shouf area, that in order not to contaminate or reduce the quality of the produced Compost. Typically, analysis of wastewater treatment plant sludge is performed on composite samples for the parameters set forth in Table 7.7. Since the sewage discharged into the plant is mainly of domestic origin, concentrations of toxic compounds such as PCBs and pesticides are expected to be negligible. Thus, analyzing the sludge for such compounds is not mandatory, especially that they incur relatively high analysis costs. Additionally, high levels of metals are not expected to be present. However, it is advisable to test the generated sludge for metal content and toxic organic compounds on a 6-month or annual basis. Moreover, bacterial and nutrient levels (NPK value) in the wastewater sludge should be determined regularly. It is important that contractors/suppliers of the plants located in these villages shall account for the presence of gas stations, lube oil service shops, and auto-mechanics in their final design of the plants, even in the case of their absence and that is to account for future growth of theses villages. Good housekeeping and the installation of oil/water separators or grease traps would be requested for such facilities especially that cooking oil could be as well disposed into domestic sewage.

Table 7.7. Sludge quality monitoring parameters

Total Solids	Copper
pH	Lead
Total Nitrogen	Mercury
Ammonia-Nitrogen	Molybdenum
Nitrate-Nitrogen	Nickel
Phosphorus	Selenium
Potassium	Zinc
Arsenic	Polychlorinated Biphenyls
Cadmium	Pathogens

It is necessary to install in-line analytical meters and measuring devices, especially for regular daily measurements, to ensure sampling reproducibility. Automatic samplers may also be useful at specific locations. The on-site presences of analytical components facilitate process control and performance monitoring and subsequently ensure compliance.

7.3.2 Impact Detection Monitoring

As mentioned earlier, impact detection monitoring relates to detecting the impact of the operation on the environment. Such monitoring shall be the responsibility of the municipal authorities. An independent monitoring organization shall be set up and financed by the concerned municipalities, or monitoring activities will be contracted to a specialized private organization. Impact monitoring includes periodic sampling from downstream wells, springs, and surface waters, and analyzing samples by preset biological as well as chemical quality control tests. The tests performed over the various springs, wells and rivers in this study, prior to the implementation of the various treatment plants, should be used as a basis in order to assess the expected positive effects or impacts of wastewater management over the various receiving water bodies in the area subsequently over the environment. It is recommended to perform quarterly monitoring (every three months) of the following springs:

- Ain el Arish (Aammatour)
- Ain Mourchid (Moukhtara).
- Ain el Fokor (Aammatour).
- Ain El Machair

The following parameters should be monitored:

- Feceal coliforms
- BOD_5
- Residual chlorine

7.4. COST OF MONITORING

As mentioned earlier, monitoring activities for the WWTPs are the reponsibility of the municipal authorities. In order to determine the budget to be allocated for the monitoring plan, the costs of tests suggested in accordance to the draft decision by the Ministry of Environment have been tabulated along with the sampling frequency. Table 7.8. presents sampling costs and the total cost for monitoring per month. Appendix I shows detailed costs on a monthly basis for process performance parameters in early, advanced and minimal sampling phases, as recommended earlier in the monitoring plan.

Table 7.8. Monitoring Cost for Process Performance Parameters

Sampling Location	*Analytical Parameter*	*Sampling frequency*[1]	*Unit price (L.L.)*	*Total/month (L.L.)*
Plant influent	Flow	D		
	pH	D		0
Primary treatment Effluent	BOD_5	D	30,000.00	900,000.00
	pH	D		0
	Total Suspended Solids	W	22,500.00	90,000.00
	Volatile Suspended Solids	W	22,500.00	90,000.00
	Temperature	D		0
Secondary Treatment Effluent	BOD_5	D	30,000.00	900,000.00
	pH	D		0
	Total Suspended Solids	1/2W	22,500.00	45,000.00
	Volatile Suspended Solids	1/2W	22,500.00	45,000.00
	Temperature	D		0
	Total Nitrogen[2]	1/2W	181,000.00	362,000.00
	Total Phosphorus	1/2W	73,000.00	146,000.00
Tertiary Treatment Effluent / final effluent.	BOD_5	D	30,000.00	900,000.00
	pH	D		0
	Total Suspended Solids	1/2W	22,500.00	45,000.00
	Volatile Suspended Solids	1/2W	22,500.00	45,000.00
	Temperature	D		0
	Total Nitrogen	1/2W	181,000.00	362,000.00
	Total Phosphorus	1/2 W	73,000.00	146,000.00
	Residual Chlorine	D	22,500.00	675,000.00
		subtotal		4,751,000.00

The unit cost for temperature as well as pH measurement is 8,000 L.L. This cost was not included in the above price list as it is highly recommended that the WWTP facility would acquire the necessary equipment for both pH and temperature daily sampling. The cost of good quality pH meters and thermometers revolve around 600,000 L.L. per unit.

Another suggestion is the establishement of a common laboratory for all the villages of higher Shouf area under the supervision of the union, for sampling and analysis for the seven WWTPs to be constructed. This laboratory would serve in developing databases, managing records and thus ensure better compliance in monitoring. More capital cost is required for laboratory equipment, and later for the permanent staff and expenses. However, this suggested on-site monitoring center

[1] D: daily, 1/W: once per week, 1/2W: once per two weeks, M: monthly, 1/2M: once per two months
[2] Carbon, Hydrogen, Nitrogen and Sulfur are sampled together using Elemental Analyzer method

laboratory would increase the overall effectiveness and ensure autonomy, and thus reduce the overall costs of monitoring in the long-run.

7.5. RECORD KEEPING AND REPORTING

Monitoring efforts would be in vain in the absence of an organized record keeping practice. It is the responsibility of the treatment plant administration, in this case the municipality, to ensure the development of a database that includes a systematic tabulation of process indicators, performed computations, maintenance schedules and logbook, and process control and performance monitoring outcomes. Such a historical database benefits both the plant operator and design engineers. The treatment plant should submit a periodic Discharge Monitoring Report (DMR) to the assigned regional authority, namely the Mohafaza and subsequently to the MoE. Such record keeping shall be requested and assured by the Union.

7.6. CONTINGENCY PLAN

The contingency plan in case of emergency was tackled in the design consideration of the plant by building a large equalization tank in order to balance the variations in the hydraulic loads of the plant that can eventually occur during a regular day or between winter and summer seasons.

Furthermore, the design took into consideration an inflated per capita consumption of water of 0.15 liters/day along with a peak population in each of the villages. As well as a trickling filter, that operates with no or little energy consumption and eventually decreasing the BOD prior to the aeration process. Extra blowers will be on stand-by to operate replacing any defective blower within the aeration tank along with the ability to increase aeration time in case of increased biological loads.

According to the requirements, set in the tender document the awarded contractor will have to perform regular and frequent maintenance check ups of the plant since he will be responsible for the operation of the plant during the first year and eventually convey technical expertise to the appointed future plant operators. These preventive measures and design considerations will ensure a continuous and uninterrupted operation the plant.

Last, not least, in the case of discharge of untreated or insufficiently treated effluent based on monitoring results, the relevant water authority should be immediately informed as well as downstream users to allow proper measures to be taken.

7.7. CAPACITY BUILDING

This USAID program comes along with a strong public participation, training and awareness program to complement the construction of the infrastructure, and support its sustainability. Considered as corner stone of the EMP the capacity-building program consists of two major parts: Specialized Training Workshops (STW) and General Awareness Seminars (GAS).

7.7.1 Operators Training

One year training to each of the concerned municipalities staff that will operate the plant will be provided by the contractor, supporting then the overall sustainability of the project and eventually convey technical expertise to the appointed future plant operators.

7.7.2 Specialized Training Workshops (STW)

STWs consist of a combination of theoretical lectures, focused training sessions, and field demonstrations that are believed to maximize workshop impacts. A highly technical training manual will be distributed to the participants to serve as a basis for future reference and application of proper environmental guidelines. These training sessions to be conducted in 2005, will contribute to the ability of the local community and stakeholders of capitalizing on the projects, and actively participating to their sustainability.

7.7.3 General Awareness Seminars (GAS)

General awareness seminars are targeted to the local community in general. Issues addressed in a GAS are less technical than those in STWs, and aim at raising awareness and improve environmental practices of the local population. It would be however rather difficult and expensive to provide these seminars to a very large portion of the local communities during the duration of the project. It is believed to be a more sustainable approach to TRAIN THE TRAINERS who will subsequently train and raise awareness in the community. These trainers include primarily school professors and NGO's that could take over this educational role. Topics to be included in these seminars could be environmental impacts from poor disposal practices, role of the local community in improving the environment and other general topics aimed to increase environmental awareness.

Awareness manuals and ready-made presentations will be prepared and provided to these trainers as tools to be used in raising awareness. Trainers would attend awareness seminars provided in schools and other public locations in order to be acquainted with the principle. Several

GASs would be conducted in order to initiate the environmental awareness in the rural communities.

7.8. INSTITUTIONAL ARRANGEMENTS

No matter how meticulously an environmental management scheme has been prepared, it will fail in the absence of predefined responsibilities and strong technical bodies. Compliance monitoring shall be the responsibility of the treatment plant administration (municipalities or a contracted operator) and thus its activities shall be budgeted for accordingly. However, in accordance with the requirements of the regulatory authority (MoE), the treatment plants should submit a periodic Discharge Monitoring Report (DMR) to the assigned enforcement authority (Mohafaza/MoIM). The assigned authority will be responsible for drawing conclusions based on the monitoring data, and deciding on specific actions to alleviate pollution impacts. The coordination with the Beirut and Mount Lebanon Water and Wastewater Establishment is also important since they are responsible for wastewater monitoring in their new mandate. On the other hand, impact detection monitoring shall be the responsibility of the municipal authorities and union. Ideally, an independent monitoring organization is set up and financed by the concerned municipalities or the Union, or monitoring activities are contracted to a specialized private organization. Figure 7.1 is an illustration of such institutional arrangement.

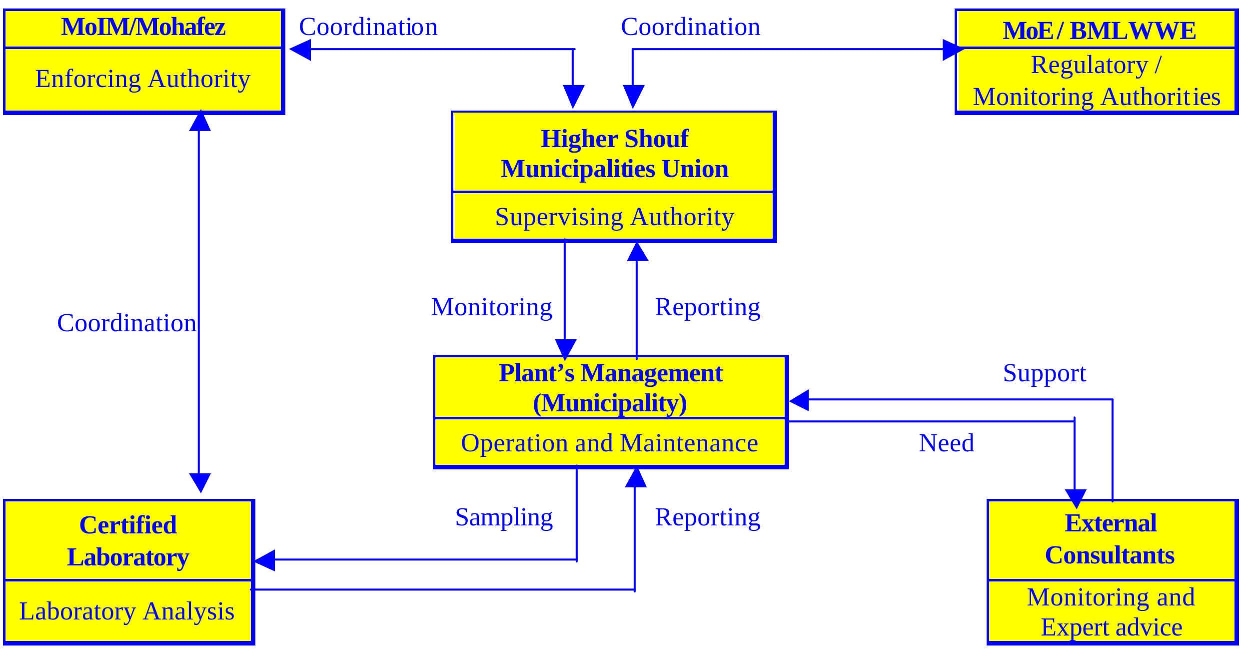


Figure 7.1. Proposed Institutional Setting

8. PUBLIC INVOLVEMENT AND PARTICIPATION

Public involvement started early in the process during the municipal election campaigns in 1997. The project then became the foremost issue being requested from the municipalities by the constituents. The Union meetings kept the various municipalities abreast of the project. Since it was a publicly initiated and supported project, public involvement was assured.

During these EIAs studies, the consultant met numerous times with the Mayors of the villages of Higher-Shouf. Specifically, the consultants met with the officials in Mrousti, Jebaa, Moukhtara, and Butmeh, all along with the assistance of PM representatives, to present the findings regarding many aspects concerning the sites location, network distribution, springs assessments, most appropriate technologies and many other aspects required to finalize the studies. Additional meetings were also set between ELARD and PM to set the Specifications, Requirements and Standards requested for compliance of contractors in the bidding process.

In the preliminary stages of the study, the municipalities were requested to fill out a questionnaire tailored towards obtaining additional relevant and specific information. The requested information related to the physical and biological environment, the socio-economic situation in the various municipalities, and general requirements pertinent to the EIA process. Appendix G includes a sample of a questionnaire that each municipality was requested to complete.

Also in conformity with EIA guidelines, a notice was posted for duration of at least 18 days at the concerned municipalities within the Union informing the public about the EIA study that is being conducted and the proposed treatment plants, and soliciting comments. A copy of the notice is included in Appendix H ***along with the EMP compliance form signed by the concerned municipality.***

On September 5, 2003, a social event initiated by PM. in the presence of the funding organization USAID and Mr. Walid Joumblat, was held in order to present to the various proponents the planned projects prospected for the Higher Shouf area.

On October 18, 2003, under the public participation program an Inception Workshop was also held to present to the various participants the overall description of the intended project, joining as well the different stakeholders to discuss the project. The various stakeholders present included municipality members, representatives of local community, local NGOs, Government representatives, Project partners and USAID. The meeting was very instructive and various questions and concerns were raised throughout the session. Appendix G includes a copy of official invitation letter, meeting agenda, the list of official invitees, actual attendance, Minutes of the meeting and the presentation for the workshop.

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APPENDIX A
TECTONIC MAP OF LEBANON; GEOLOGICAL MAP OF STUDY AREAS (JEBAA/MROUSTI & MOUKHTARA/BUTMEH); CROSS SECTIONS

APPENDIX B
TOPOGRAPHIC MAPS INDICATING SAMPLING LOCATIONS; LABORATORY ANALYTICAL RESULTS – SPRINGS WATER – BAROUK RIVER.

APPENDIX C
ARCHITECTURAL DRAWING OF AN EAAS PLANT TO BE IMPLEMENTED IN THE VILLAGES.

APPENDIX D
SURVEYED SITES LOCATION.

APPENDIX E
SLUDGE AND EFFLUENT MANAGEMENT

INTRODUCTION

Sludge and effluent disposal by surface application is performed in an environmentally safe manner according to different restrictions and considerations. The US EPA formulated 40 CFR Part 503 to regulate the use or disposal of sludge in order to protect public health and the environment. In specific, subpart B of the part 503 rule prohibits the land application of sewage sludge that exceeds specified limits. Those standards should be followed as they represent the most comprehensive international standards developed according to risk analysis.

Effluent cannot be directly disposed to land unless it complies with the wastewater quality standards (guidelines for water re-use or disposal suggested by the EPA). Furthermore, sludge cannot be frequently disposed on the same soil. If land application is to be performed, sludge should be collected and stored, and then applied according to an application rate, which depends on the site characteristics and on the sludge quality (level of pollutants) (according to sludge disposal guidelines suggested by the EPA).

The present appendix presents the restrictions preventing land application of the proposed effluent and provides the standards and considerations that should be achieved if land application was to be the sludge disposal method. The difference between sludge disposal and effluent disposal should be considered: effluent disposal is performed according to the wastewater quality standards, and sludge disposal according to sewage sludge standards, and with different application rates.

LAND TREATMENT

Land treatment is characterized as spreading the waste (effluent or sludge) on the soil surface or incorporating it into the upper few centimeters by mechanical manipulation. The method of application depends on the physical, chemical, and toxic nature of the waste and the rate of biodegradation desired. Sprinkler, flood, or drip-type application could be used to apply liquids. Because of their fluid nature, they penetrate the soil and thus, do not require mechanical soil incorporation unless they carry significant amounts of solids. The single purpose of land treatment as opposed to land utilization is final disposal of the waste with little or no demand of the waste to function as a resource.

Destruction of the soil for vegetative growth is not a part of land treatment. Land treatment must provide sound, environmentally safe disposal of waste residuals through biological, chemical, and physical interactions occurring in soils. The inorganic metal components are expected to biodegrade through the activity of the indigenous soil microorganisms. The inorganic metal components are expected to attenuate (or immobilize) primarily through physical-chemical interactions with the soil (Fuller, 1988).

Table E.1 and Table E.2, present the general requirement for sludge disposal and effluent disposal on forestlands. Detailed analysis and considerations will be presented in the report.

Table E.1. Summary of typical characteristics of sewage sludge land application practices (EPA, 1992)

Characteristics	*Forest land application*
Application rates	Varies: normal range in dry weight of 10 to 220 t/ha/yr. (4 to 100 T/ac/yr.) depending on soil, tree species, sludge quality, etc. typical rate is about 18 t/ha/yr. (8 T/ac/yr.)
Application frequency	Usually applied annually or at 3 to 5-year intervals
Useful life of application site(s)	Usually limited by accumulated metal loading in total sewage sludge applied. With most sewage sludge a useful life of 20 to 55 years or more is typical.
Sewage sludge scheduling	Scheduling affected by climate and maturity of trees.
Application constraints	Limited by part 503 agronomic rate management practice requirement.

Table E.2. EPA guidelines for water reuse in wildlife habitats (EPA, 1992)

Factor	*Requirement*
Treatment	Secondary and disinfection
Effluent quality	BOD< 30 mg/l SS<30 mg/l Fecal coliform <200 fecalcoli/100ml (The number of fecal coliform organisms should not exceed 800/100 ml in any sample)
Effluent monitoring	BOD – weekly SS - daily Coliform - daily Cl_2 residual – continuous
Other considerations	Ground water monitoring Temperature pH

SLUDGE DISPOSAL

EPA REQUIREMENTS FOR SLUDGE DISPOSAL

EPA developed the federal part 503 rule (40 CFR Part 503) that establishes requirements for land application of sewage sludge. Subpart B of the part 503 rule prohibits the land application of sludge that exceeds pollutant limits termed “ceiling concentration limits” for 10 metals and places restrictions on sludge exceeding additional pollutant limits, which are the cumulative pollutant loading rate limits and the annual pollutant loading rate limits. The requirements for land disposal are presented in Table E.3, and further explained in the following sections.

Table E.3. Part 503 land application pollutant limits for sewage sludge (EPA, 1995)

Pollutant	***Ceiling concentration limits (mg/kg)***	***Cumulative pollutant loading rate limits (kg/ha)***	***Annual pollutant loading rate limits (kg/ha per 365-day period)***
Arsenic	75	41	2.0
Cadmium	85	39	1.9
Chromium	3,000	3,000	150
Copper	4,300	1,500	75
Lead	840	300	15
Mercury	57	17	0.85
Molybdenum	75	--	--
Nickel	420	420	21
Selenium	100	100	5.0
Zinc	7,500	2,800	140

Ceiling concentration limits (EPA, 1995)

All sewage sludge applied to land must meet part 503 ceiling concentration limits for 10 regulated pollutants. Ceiling concentration limits are the maximum allowable concentration of a pollutant in sewage sludge to be land applied. If the ceiling concentration of any one of the regulated pollutants is exceeded, the sewage sludge cannot be land applied.

Cumulative pollutant loading rates (CPLRs)

A CPLR is the maximum amount of pollutant that can be applied to a site by all sludge applications. When the CPLR is reached at the application site for any one of the 10 metals no additional sludge can be applied.

Annual pollutant loading rates (APLRs)

APLR is the maximum amount of a pollutant that can be applied to a site within a 12-month period from sludge. The pollutant concentration in sludge multiplied by the “whole annual sludge application rate” must not cause any of the APLR to be exceeded.

Pathogen requirements (EPA, 1995)

The density of fecal coliform in the sewage sludge must be less than 1,000 most probable number (MPN) per gram total solids (dry-weight basis) or the density of Salmonella sp. bacteria in the sewage sludge must be less than 3 MPN per 4 grams of total solids (dry-weight basis).

Vector Attraction Reduction Requirements (EPA, 1995)

Subpart D in Part 503 establishes 10 options for demonstrating that sludge that is land applied meets requirements for vector attraction reduction (Table E.4). The options can be divided into two general approaches for controlling the spread of disease via vectors (such as insects, rodents, and birds):

- Reducing the attractiveness of the sewage sludge to vectors (Options 1 to 8).
- Preventing vectors from coming into contact with the sewage sludge (Options 9 and 10).

Compliance with the vector attraction reduction requirements using one of the options described below must be demonstrated separately from compliance with requirements for reducing pathogens in sewage sludge. Thus, demonstration of adequate vector attraction reduction does not demonstrate achievement of adequate pathogen reduction. Part 503 vector attraction reduction requirements are summarized below:

Table E.4. Summary of Vector Attraction Reduction Requirements for Land Application of Sewage Sludge Under Part 503 (U.S. EPA 1992b)

Requirement	What Is Required?	Most Appropriate For:
Option 1: Reduction in volatile solid content 503.33(b)(1)	At least 38% reduction in volatile solids during sewage sludge treatment	Sewage sludge processed by: · Anaerobic biological treatment · Aerobic biological treatment · Chemical oxidation
Option 2: Additional digestion of anaerobically digested sewage sludge 503.33(b)(2)	Less than 17% additional volatile solids loss during bench-scale anaerobic batch digestion of the sewage sludge for 40 additional days at 30°C to 37°C (86°F to 99°F)	Only for anaerobically digested sewage sludge
Option 3: additional digestion of aerobically digested sewage sludge 503.33(b)(3)	Less than 15% additional volatile solids reduction during bench-scale aerobic batch digestion for 30 additional days at 20°C (68°F)	Only for aerobically digested sewage sludge with 2% or less solids—e.g., sewage sludge treated in extended aeration plants
Option 4: specific oxygen uptake rate for aerobically digested sewage sludge treated in an aerobic process 503.33(b)(4)	SOUR at 20°C (68°F) is <1.5 mg oxygen/hr/g total sewage sludge solids	Sewage sludge from aerobic processes (should not be used for composted sludge). Also for sewage sludge that has been deprived of oxygen for longer than 1–2 hours.
Option 5: aerobic processes at greater than 40°C 503.33(b)(5)	Aerobic treatment of the sewage sludge for at least 14 days at over 40°C (104°F) with an average temperature of over 45°C (113°F)	Composted sewage sludge (Options 3 and 4 are likely to be easier to meet for sewage sludge from other aerobic processes)
Option 6: addition to alkali 503.33(b)(6)	Addition of sufficient alkali to raise the pH to at least 12 at 25°C (77°F) and maintain a pH =12 for 2 hours and a pH <11.5 for 22 more hours	Alkali-treated sewage sludge (alkalies include lime, fly ash, kiln dust, and wood ash)
Option 7: moisture reduction of sewage sludge containing no un-stabilized solids 503.33(b)(7)	Percent solids <75% prior to mixing with other materials	Sewage sludge treated by an aerobic or anaerobic process (i.e., sewage sludge that do not contain un-stabilized solids generated in primary wastewater treatment)
Option 8: moisture reduction of sewage sludge containing un-stabilized solids 503.33(b)(8)	Percent solids <90% prior to mixing with other materials	Sewage sludge that contain un-stabilized solids generated in primary wastewater treatment (e.g., any heat-dried sewage sludge)
Option 9: injection of sewage sludge 503.33(b)(9)	Sewage sludge is injected into soil within 8 hours after the pathogen reduction process so that no significant amount of sewage sludge is present on the land surface 1 hour after injection,	Liquid sewage sludge applied to the land.
Option 10: incorporation of sewage sludge into the soil 503.33(b)(10)	Sewage sludge must be applied to the land surface within 8 hours after the pathogen reduction process, and must be incorporated within 6 hours after application.	Sewage sludge applied to the land.

PHYSICAL CHARACTERISTICS OF POTENTIAL LAND APPLICATION SITES (EPA, 1995)

The physical characteristics of concern are:

- Topography (Table E.5)
- Soil permeability, infiltration, and drainage patterns
- Depth to ground water
- Proximity to surface water

Potentially unsuitable areas for sewage sludge application:

- Areas bordered by ponds, lakes, rivers, and streams without appropriate buffer areas.
- Wetlands and marshes
- Steep areas with sharp relief.
- Undesirable geology (karst, fractured bedrock) (if not covered by a sufficiently thick soil column).
- Undesirable soil conditions (rocky, shallow).
- Areas of historical or archeological significance.
- Other environmentally sensitive areas such as floodplains or intermittent streams, ponds, etc., as specified in the Part 503 regulation.

Table E.5. Recommended Slope Limitations for Land Application of Sludge

Slope	Comment
0-3%	Ideal; no concern for runoff or erosion of liquid or dewatered sludge.
3-6%	Acceptable for surface application of liquid or dewatered sludge; slight risk of erosion.
6-12%	Injection of liquid sludge required in most cases, except in closed drainage basin and/or areas with extensive runoff control. Surface application of dewatered sludge is usually acceptable.
12-15%	No liquid sludge application without effective runoff control; surface application of dewatered sludge is acceptable, but immediate incorporation is recommended.
Over 15%	Slopes greater than 15% are only suitable for sites with good permeability (e.g., forests), where the steep slope length is short (e.g., mine sites with a buffer zone downslope), and/or the steep slope is a minor part of the total application area.

Soil Permeability and Infiltration

Permeability (a property determined by soil pore space, size, shape, and distribution) refers to the ease with which water and air are transmitted through soil. Fine-textured soils generally possess slow or very slow permeability, while the permeability of coarse-textured soils ranges from moderately rapid to very rapid. A medium textured soil, such as a loam, tends to have moderate to slow permeability.

Soil Drainage

Soils classified as (1) very poorly drained, (2) poorly drained, or (3) somewhat poorly drained may be suitable for sewage sludge application if runoff control is provided. Soils classified as (1) moderately well drained, (2) well drained, or (3) somewhat excessively drained are generally suitable for sewage sludge application. Typically, a well-drained soil is at least moderately permeable.

Surface Hydrology, Including Floodplains and Wetlands

The number, size and nature of surface water bodies on or near a potential sludge land application site are significant factors in site selection due to potential contamination from site runoff. Areas subject to high runoff have severe limitations for sludge application.

Ground Water

For preliminary screening of potential sites, it is recommended that the following ground water information for the land application area be considered:

- Depth to ground water (including historical highs and lows).
- An estimate of ground water flow patterns.

The greater the depth to the water table, the more desirable a site is for sludge application. Sludge should not be placed where there is potential for direct contact with the ground-water table. The actual thickness of unconsolidated material above a permanent water table constitutes the effective soil depth. The desired soil depth may vary according to sludge characteristics, soil texture, soil pH, method of sludge application, and sludge application rate. Recommended Depth to Ground Water:

- Drinking Water Aquifer: 2 m
- Excluded Aquifer (not used as potable water supplies): 0.7 m

The type and condition of consolidated material above the water table is also of major importance for sites where high application rates of sewage sludge are desirable. Fractured rock may allow leachate to move rapidly. Unfractured bedrock at shallow depths will restrict water movement, with the potential for ground water mounding, subsurface lateral flow, or poor drainage. Limestone bedrock is of particular concern where sinkholes may exist. Sinkholes, like fractured rock, can accelerate the movement of leachate to ground water. Thus, potential sites with potable ground water in areas underlain by fractured bedrock, by unfractured rock at shallow depths, or with limestone sinkholes should be avoided.

Table E.6. Soil Limitations for Sewage Sludge Application to Agricultural Land at Nitrogen Fertilizer Rates

Soil features affecting use	Degree of soil limitation		
	Slight	Moderate	Severe
Slope[a]	Less than 6%	6 to 12%	More than 12%
Depth to seasonal water table	More than 1.2 m	0.6 to 1.2 m	Less than 1 m
Flooding and ponding	None	None	Occasional to frequent [b]
Depth to bedrock	More than 1.2 m	0.6 to 1.2 m	Less than 0.61 m
Permeability of the most restricting layer above a 1-m depth	0.24 to 0.8 cm/hr	0.8 to 2.4 cm/hr 0.08 to 0.24 cm/hr	Less than 0.08 cm/hr More than 2.4 cm/hr
Available water capacity	More than 2.4 cm	1.2 to 2.4 cm	Less than 1.2 cm

[a] Slope is an important factor in determining the runoff that is likely to occur. Most soils on 0 to 6% slopes will have slow to very slow runoff; soils on 6 to 12% slopes generally have medium runoff; and soils on steeper slopes generally have rapid to very rapid runoff.
b Land application may be difficult under extreme flooding or ponding conditions.
Metric conversions: 1 ft = 0.3048 m, 1 in = 2.54 cm.

CLIMATE

Analysis of climatological data is an important consideration for the preliminary planning phase. Rainfall, temperature, evapotranspiration, and wind may be important climatic factors affecting land application of sludge, selection of land application practices, and site management. Table E.7 highlights the potential impacts of some climatic regions on the land application of sludge.

Table E.7. Potential Impacts of Climatic Regions on Land Application of Sewage Sludge

Impact	Warm/Arid	Warm/Humid	Cold/Humid
Operation Time	Year-round	Seasonal	Seasonal
Salt Buildup Potential	High	Low	Moderate
Leaching Potential	Low	High	Moderate
Runoff Potential	Low	High	High

SELECTION OF LAND APPLICATION PRACTICE (EPA, 1995)

Table E.8 presents an example of a ranking system for forest sites, based on consideration of topography, soils and geology, vegetation, water re-sources, climate, transportation, and forest access. Several other considerations should be integrated into the decision-making process, including:

- Compatibility of sewage sludge quantity and quality with the specific land application practice selected.
- Public acceptance of both the practice(s) and site(s) selected.

- Anticipated design life, based on assumed application rate, land availability (capacity), projected heavy metal loading rates (if Part 503 cumulative pollutant loading rates are being met), and soil properties.

Table E.8. Relative Ranking for Forest Sites for Sewage Sludge Application

Factor	***Relative Rank***
Topography	
Slope	
Less than 10%	High
10-20%	Acceptable
20-30%	Low
Over 30%	Low
Site continuity (somewhat subjective)	
No draws, streams, etc., to buffer	High
1 or 2 requiring buffers	Acceptable
Numerous discontinuities	Low
Forest System	
Percent of forest system in place	Low-High
Erosion hazard	
Little (good soils, little slope)	High
Great	Low-Acceptable
Soil and Geology	
Soil type	
Sandy gravel (outwash, Soil Class I)	High
Sandy (alluvial, Soil Class II)	High
Well graded loam (ablation till, Soil Class IV)	Acceptable
Silty (residual, Soil Class V)	Acceptable
Clayey (lacustrine, Soil Class IV)	Low
Organic (bogs)	Low
Depth of soil	
Deeper than 10 ft	High
3-10 ft	High
1-3 ft	Acceptable
Less than 1 ft	Low
Geology (subjective, dependent upon aquifer)	
Sedimentary bedrock	Acceptable-High
Andesitic basalt	Acceptable-High
Basal tills	Low-Acceptable
Lacustrine	Low
Vegetation (sensitive-rare)	Low-high

SOIL SAMPLING AND ANALYSIS TO DETERMINE AGRONOMIC RATES (EPA, 1995)

Designing the agronomic rate for land application of sewage sludge is one of the key elements in the Part 503 rule for ensuring that land application does not degrade ground water quality through nitrate contamination. The Part 503 rule defines agronomic rate as: the whole sludge application rate (dry weight basis) designed: (1) to provide the amount of nitrogen needed by the vegetation on the land and (2) to minimize the amount of nitrogen in the sludge that leach beyond the root zone of the vegetation grown on the land to the ground water (40 CFR 503.11(b).

Designing the agronomic rate for a particular area requires knowledge of (1) soil fertility, especially available N and P; and (2) characteristics of the sludge, especially amount and forms of N (organic N, NH_4, and NO_3). The complex interactions between these factors and climatic variability (which affects soil-moisture related N transformations) make precise prediction of crop N requirements difficult.

Major constituents that may need to be tested in soils include:

- NO_3-N as an indicator of plant-available N in the soil. Where applicable, these tests should be made for calculating initial sludge application rates, and can possibly be used in subsequent years.

- C/N ratio, which provides an indication of the potential for immobilization of N in sludge as a result of decomposition of plant residues in the soil and at the soil surface. This is especially relevant for forestland application sites as well as for agricultural purposes.

DETERMINING SEWAGE SLUDGE APPLICATION RATES FOR FOREST SITES (EPA, 1995)

Sewage sludge application rates at forest sites usually are based on tree N requirements.

Nitrogen dynamics of forest systems are somewhat complex because of recycling of nutrients in decaying litter, twigs and branches, and the immobilization of the NH_4^+ contained in sludge as a result of decomposition of these materials.

Concentrations of trace elements (metals) in sludge may limit the cumulative amount of sewage sludge that can be placed on a particular area.

Nitrogen applications cannot exceed the ability of the forest plants to utilize the N applied, with appropriate adjustments for losses.

Cumulative metal loading limits cannot exceed the cumulative pollutant loading rates (CPLRs) in the Part 503 rule.

Nitrogen Uptake and Dynamics in Forests

In general, uptake and storage of nutrients by forests can be large if the system is correctly managed and species respond to sludge. The trees and understory utilize the available N from sludge, resulting in an increase in growth. There is a significant difference between tree species in their uptake of available N. In addition, there is a large difference between the N uptake by seedlings, vigorously growing trees, and mature trees. Finally, the amount of vegetative understory on the forest floor will affect the uptake of N; dense understory vegetation markedly increases N uptake.

Calculation of sludge application rates requires considerations of nitrogen transformations in addition to N mineralization and ammonia volatilization from the sewage sludge: (1) denitrification, (2) uptake by under-story, and (3) soil immobilization for enhancement of forest soil organic-N (ON) pools.

Nitrogen Leaching

Typically, N is the limiting constituent for land applications of sludge because when excess N is applied, it often results in nitrate leaching. The N available from sludge addition can be microbially transformed into NO3 - through a process known as nitrification. Because NO3 - is negatively charged, it easily leaches to the ground water with percolating rainfall.

EQUIPMENT FOR SEWAGE SLUDGE APPLICATION AT FOREST SITES (EPA, 1995)

There are four general types of methods for applying sewage sludge to forests: (1) direct spreading; (2) spray irrigation with either a set system or a traveling gun; (3) spray application by an application vehicle with spray cannon; and (4) application by a manure-type spreader.

The main criterion used in choosing a system is the liquid content of the sewage sludge. Methods 1, 2, and 3 are effective for liquid sewage sludge (2% to 8% solids); Methods 1 and 2 can be used for semi-solid sewage sludge (8% to 18% solids); and only Method 4 is acceptable for solid sewage sludge (20% to 40% solids).

SCHEDULING (EPA, 1995)

Sludge applications to forest sites can be made either annually or once every several years. Annual applications are designed to provide N only for the annual uptake requirements of the trees, considering volatilization and denitrification losses and mineralization from current and prior years. An application one-year followed by a number of years when no applications are made utilizes soil storage (immobilization) of nitrogen to temporarily tie up excess nitrogen that will become available in later years.

In a multiple-year (e.g., every 3 to 5 years) application system, the forest floor, vegetation, and soil have a prolonged period to return to normal conditions, and the public can use the site for recreation in the non-applied years. Application rates, however, are not simply an annual rate multiplied by the number of years before reapplication, but rather need to be calculated so that no NO_3 - leaching occurs.

Scheduling sludge application also requires a consideration of climatic conditions and the age of the forest. High rainfall periods and/or freezing conditions can limit sewage sludge applications in almost all situations. The Part 503 regulation prohibits bulk sewage sludge from being applied to forestland that is flooded, frozen, or snow-covered so that the sewage sludge enters wetlands or other surface waters.

EFFLUENT DISPOSAL

CRITERIA DETERMINING EFFLUENT DISPOSAL (FULLER, 1988)

Effluent acceptable for disposal should meet certain criteria of quality. Superimposed on these are loading rates. The effluent should first meet the following requirements before the loading rate is determined:

- Capability of biodegradation of solids or soluble components
- No long-term toxicity to plants or microorganisms
- Each migration at practical rates of application to the ground water
- No adverse influence on the natural physical and chemical properties of the soil at reasonable rates of application
- No long-term limitation of land productivity

Further criteria and explanations will be provided in the following section.

The criteria determining loading rates are:

1. Effluent quality: Organic matter, BOD, COD, total organic carbon, TOC, heavy metals, total dissolved solids (TDS), suspended solids (SS), nitrogen, phosphorus, sodium absorption ratio (SAR), boron, bacteriological composition, organic chemicals, organic solvents.
2. Soil quality: Texture, structure, permeability, infiltration, presence of confining soil barriers, depth to water table, drainage
3. Climate: Rainfall amount and intensity factor, temperature, wind velocity and direction, evapotranspiration.
4. Topography: Slope, soil and water erosion potential, flood hazard, topography of watershed

5. Geologic formation: Depth to bedrock, limestone
6. Groundwater: depth to ground water, direction, and rate of flow, perched water tables, and location, depth, and quality of wells.

EPA EFFLUENT RE-USE CRITERIA

The effluent should not alter the natural ecosystem present in the site, meaning that it should not lead to plant toxicity or underground water contamination. Effluents from tanneries are not usually disposed in forestlands, and this application is currently examined and studied. Until further advances and clarifications, the effluent should have the quality of reclaimed water for irrigation (which is developed to protect plant and human health) if it is to be disposed in forests. The following criteria and requirements should be achieved (Table E.9 and Table E.10).

Reclaimed water quality

The constituents in reclaimed water of concern are salinity, sodium, trace elements, excessive chlorine residual, and nutrients.

- Salinity: Salt accumulation can be especially detrimental during germination and when plants are young even at relatively low concentrations. Salinity may be reported as TDS. (TDS mg/l * 0.00156 = EC mmhos/cm). Salinity depends on the plant salt tolerance, and on the soil drainage and leaching characteristics (soils should be properly drained and adequately leached (leaching requirements) to prevent salt buildup). The extent of salt accumulation in the soil depends on the salt concentration in the water and the rate at which it is removed by leaching.
- Sodium: the potential influence sodium may have on soil properties is indicated by the sodium-adsorption-ratio (SAR = NA/{v [(Ca + Mg)/2]}). Sodium salts influence the exchangeable cation composition of the soil, which lowers the permeability, which impairs the infiltration of water into the soil.
- Trace elements of greatest concern at elevated levels are Cd, Co, Mb, Ni, and Zn.
- Chlorine residual: free chlorine residual at concentrations less than 1mg/l usually poses no problems to plants. However, some sensitive plants may be damaged at levels as low as 0.05 mg/l. some woody plants may accumulate chlorine in the tissue to toxic levels. Excessive chlorine has similar leaf-burning effect as sodium and chloride when sprayed directly on foliage. Chlorine at concentrations greater than 5 mg/l causes severe damage to most plants.

Table E.9. Recommended limits for constituents in reclaimed water for irrigation of plants (EPA, 1992)

Constituent	***Long-term use (mg/l)***	***Remark***
Aluminum	5.0	Can cause non-productivity in acid soils, soils with pH 5.5-8 will precipitate the ion and eliminate toxicity
Arsenic	0.1	Toxicity to plants varies widely ranging from 12 mg/l to < 0.05 mg/l
Beryllium	0.1	Toxicity to plants varies widely ranging from 5 mg/l to < 0.5 mg/l
Boron	0.75	Toxicity to many sensitive plants at 1 mg/l, most grasses relatively tolerant at 2.0 to 10 mg/l
Cadmium	0.01	Toxic to some plants at levels as low as 0.1 mg/l
Chromium	0.1	Lack of knowledge on toxicity to plants
Cobalt	0.05	Tends to be inactivated by neutral and alkaline soils
Copper	0.2	Toxic to a number of plants at 0.1 to 1.0 mg/l
Fluoride	1.0	Inactivated by neutral and alkaline soils
Iron	5.0	Contributes to soil acidification and loss of essential P and Molybdenum.
Lead	5.0	Can inhibit plant cell growth at high concentrations
Lithium	2.5	Mobile in soil, toxic to some plants at low doses (0.075mg/l)
Manganese	0.2	Toxic to some plants at a few tenths to a few mg/l in acid soils
Molybdenum	0.01	
Nickel	0.2	Toxic to a number of plants at 0.5 to 1.0 mg/l; reduced toxicity at neutral or alkaline pH
Selenium	0.02	Toxic to plants at low concentrations
Vanadium	0.1	Toxic to many plants
Zinc	2.0	Reduced toxicity at increased pH (6 or above) and in fine textured soils
Other parameter		
Constituent	Recommended limit	Remarks
pH	6.0	Indirect effects on plant growth
TDS	500-2,000 mg/l	Above 2,000 mg/l can be regularly used only if all plants are tolerant and soils are permeable
Free chlorine residual	< 1 mg/l	

Table E.10. EPA suggested guidelines for water reuse in wildlife habitats

FACTOR	REQUIREMENT
TREATMENT	SECONDARY AND DISINFECTION
EFFLUENT QUALITY	BOD< 30 MG/L, SS=30 MG/L FECAL COLIFORM =200 FECALCOLI/100ML (THE NUMBER OF FECAL COLIFORM ORGANISMS SHOULD NOT EXCEED 800/100 ML IN ANY SAMPLE)
EFFLUENT MONITORING	BOD – WEEKLY, SS – DAILY, COLIFORM – DAILY, CL_2 RESIDUAL – CONTINUOUS
OTHER CONSIDERATIONS	GROUND WATER MONITORING, TEMPERATURE, PH

APPENDIX F
WASTEWATER TREATMENT AND USE IN AGRICULTURE - FAO IRRIGATION AND DRAINAGE PAPER 47. (SECTION 5)

IRRIGATION WITH WASTEWATER

Conditions for successful irrigation
Strategies for managing treated wastewater on the farm
Crop selection
Selection of irrigation methods
Field management practices in wastewater irrigation
Planning for wastewater irrigation

CONDITIONS FOR SUCCESSFUL IRRIGATION

Amount of water to be applied
Quality of water to be applied
Scheduling of irrigation
Irrigation methods
Leaching
Drainage

Irrigation may be defined as the application of water to soil for the purpose of supplying the moisture essential for plant growth. Irrigation plays a vital role in increasing crop yields and stabilizing production. In arid and semi-arid regions, irrigation is essential for economically viable agriculture, while in semi-humid and humid areas, it is often required on a supplementary basis.

At the farm level, the following basic conditions should be met to make irrigated farming a success:

- The required **amount** of water should be applied;
- The water should be of acceptable **quality;**
- Water application should be properly **scheduled;**
- Appropriate irrigation **methods** should be used;
- Salt accumulation in the root zone should be prevented by means of **leaching;**
- The rise of water table should be controlled by means of appropriate **drainage;**
- Plant **nutrients** should be managed in an optimal way.

The above requirements are equally applicable when the source of irrigation water is treated wastewater. Nutrients in municipal wastewater and treated effluents are a particular advantage of these sources over conventional irrigation water sources and supplemental fertilizers are sometimes not necessary. However, additional environmental and health requirements must be taken into account when treated wastewater is the source of irrigation water.

Amount of water to be applied

It is well known that more than 99 percent of the water absorbed by plants is lost by transpiration and evaporation from the plant surface. Thus, for all practical purposes, the water requirement of crops is equal to the evapotranspiration requirement; ETc. Crop evapotranspiration is mainly determined by climatic factors and hence can be estimated with reasonable accuracy using meteorological data. An extensive review of this subject and guidelines for estimating ETc, prepared by Doorenbos and Pruitt, are given in Irrigation and Drainage Paper 24 (FAO 1977). A computer program, called CROPWAT, is available in FAO to determine the water requirements of crops from climatic data. Table F-1presents the water requirements of some selected crops, reported by Doorenbos and Kassam (FAO 1979). It should be kept in mind that the actual amount of irrigation water to be applied will have to be adjusted for effective rainfall, leaching requirement, application losses, and other factors.

Quality of water to be applied

The guidelines presented are indicative in nature and will have to be adjusted depending on the local climate, soil conditions, and other factors. In addition, farm practices, such as the type of crop to be grown, irrigation method, and agronomic practices, will determine largely the quality suitability of irrigation water. Some of the important farm practices aimed at optimizing crop production when treated sewage effluent is used as irrigation water will be discussed in this chapter.

Table F 1: WATER REQUIREMENTS, SENSITIVITY TO WATER SUPPLY AND WATER UTILIZATION EFFICIENCY OF SOME SELECTED CROPS

Crop	**Water requirements (mm/growing period)**	**Sensitivity to water supply (ky)**	**Water utilization efficiency for harvested yield, Ey, kg/m^3 (% moisture)**
Alfalfa	800-1600	low to medium-high (0.7-1.1)	1.5-2.0 hay (10-15%)
Banana	1200-2200	high (1.2-1.35)	plant crop: 2.5-4 ratoon: 3.5-6 fruit (70%)
Bean	300-500	medium-high (1.15)	lush: 1.5-2.0 (80-90%) dry: 0.3-0.6 (10%)
Cabbage	380-500	medium-low (0.95)	12-20 head (90-95%)
Citrus	900-1200	low to medium-high (0.8-1.1)	2-5 fruit (85%, lime: 70%)
Cotton	700-1300	medium-low (0.85)	0.4-0.6 seed cotton (10%)
Groundnut	500-700	low	0.6-0.8

		(0.7)	unshelled dry nut (15%)
Maize	500-800	high (1.25)	0.8-1.6 grain (10-13%)
Potato	500-700	medium-high (1.1)	4-7 fresh tuber (70-75%)
Rice	350-700	high	0.7-1.1 paddy (15-20%)
Safflower	600-1200	low (0.8)	0.2-0.5 seed (8-10%)
Sorghum	450-650	medium-low (0.9)	0.6-1.0 grain (12-15%)
Wheat	450-650	medium high (spring: 1.15; winter: 1.0)	0.8-1.0 grain (12-15%)

Source: FAO(1979)

Scheduling of Irrigation

To obtain maximum yields, water should be applied to crops before the soil moisture potential reaches a level at which the evapotranspiration rate is likely to be reduced below its potential. The relationship of actual and maximum yields to actual and potential evapotranspiration is illustrated in the following equation:

$$\left(1-\frac{Y_a}{Y_m}\right) = ky\left(1-\frac{ET_a}{ET_m}\right)$$

Where:

Y_a = actual harvested yield
Y_m = maximum harvested yield
ky = yield response factor
ET_a = actual evapotranspiration
ET_m = maximum evapotranspiration

Several methods are available to determine optimum irrigation scheduling. The factors that determine irrigation scheduling are: available water holding capacity of the soils, depth of root zone, evapotranspiration rate, and amount of water to be applied per irrigation, irrigation method and drainage conditions.

Irrigation methods

Many different methods are used by farmers to irrigate crops. They range from watering individual plants from a can of water to highly automated irrigation by a centre pivot system.

However, from the point of wetting the soil, these methods can be grouped under five headings, namely:

i. **Flood irrigation -** water is applied over the entire field to infiltrate into the soil (e.g. wild flooding, contour flooding, borders, basins, etc.).

ii. **Furrow irrigation -** water is applied between ridges (e.g. level and graded furrows, contour furrows, corrugations, etc.). Water reaches the ridge, where the plant roots are concentrated, by capillary action.

iii. **Sprinkler irrigation -** water is applied in the form of a spray and reaches the soil very much like rain (e.g. portable and solid set sprinklers, travelling sprinklers, spray guns, centre-pivot systems, etc.). The rate of application is adjusted so that it does not create ponding of water on the surface.

iv. **Sub-irrigation -** water is applied beneath the root zone in such a manner that it wets the root zone by capillary rise (e.g. subsurface irrigation canals, buried pipes, etc.). Deep surface canals or buried pipes are used for this purpose.

v. **Localized irrigation -** water is applied around each plant or a group of plants so as to wet locally and the root zone only (e.g. drip irrigation, bubblers, micro-sprinklers, etc.). The application rate is adjusted to meet evapotranspiration needs so that percolation losses are minimized.

Table F 2 presents some basic features of selected irrigation systems as reported by Doneen and Westcot (FAO 1988).

Table F 2: BASIC FEATURES OF SOME SELECTED IRRIGATION SYSTEMS

Irrigation method	**Topography**	**Crops**	**Remarks**
Widely spaced borders	Land slopes capable of being graded to less than 1 % slope and preferably 0.2%	Alfalfa and other deep rooted close-growing crops and orchards	The most desirable surface method for irrigating close-growing crops where topographical conditions are favourable. Even grade in the direction of irrigation is required on flat land and is desirable but not essential on slopes of more than 0.5%. Grade changes should be slight and reverse grades must be avoided. Cross slops is permissible when confined to differences in elevation between border strips of 6-9 cm. Water application efficiency 45-60%.
Graded contour furrows	Variable land slopes of 2-25 % but preferable less	Row crops and fruit	Especially adapted to row crops on steep land, though hazardous due to possible erosion from heavy rainfall. Unsuitable for rodent-infested fields or soils that crack excessively. Actual grade in the direction of irrigation 0.5-1.5%. No grading required beyond filling gullies and removal of abrupt ridges. Water application efficiency 50-65%.
Rectangular checks (levees)	Land slopes capable of being graded so single or multiple tree basins will be levelled within 6 cm	Orchard	Especially adapted to soils that have either a relatively high or low water intake rate. May require considerable grading. Water application efficiency 40-60%.
Sub-irrigation	Smooth-flat	Shallow rooted	Requires a water table, very permeable subsoil conditions

		crops such as potatoes or grass	and precise levelling. Very few areas adapted to this method. Water application efficiency 50-70%.
Sprinkler	Undulating 1->35% slope	All crops	High operation and maintenance costs. Good for rough or very sandy lands in areas of high production and good markets. Good method where power costs are low. May be the only practical method in areas of steep or rough topography. Good for high rainfall areas where only a small supplementary water supply is needed. Water application efficiency 60-70 %.
Localized (drip, trickle, etc.)	Any topographic condition suitable for row crop farming	Row crops or fruit	Perforated pipe on the soil surface drips water at base of individual vegetable plants or around fruit trees. Has been successfully used in Israel with saline irrigation water. Still in development stage. Water application efficiency 75-85 %.

Source: FAO (1988)

Leaching

Under irrigated agriculture, a certain amount of excess irrigation water is required to percolate through the root zone to remove the salts, which have accumulated as a result of evapotranspiration from the original irrigation water. This process of displacing the salts from the root zone is called leaching and that portion of the irrigation water that mobilizes the excess of salts is called the leaching fraction, LF.

$$\text{Leaching Fraction (LF)} = \frac{\text{depth of water leached below the root zone}}{\text{depth of water applied at the surface}}$$

Salinity control by effective leaching of the root zone becomes more important as irrigation water becomes more saline.

Drainage

Drainage is defined as the removal of excess water from the soil surface and below to permit optimum growth of plants. Removal of excess surface water is termed surface drainage while the removal of excess water from beneath the soil surface is termed sub-surface drainage. The importance of drainage for successful irrigated agriculture has been well demonstrated. It is particularly important in semi-arid and arid areas to prevent secondary salinization. In these areas, the water table will rise with irrigation when the natural internal drainage of the soil is not adequate. When the water table is within a few meters of the soil surface, capillary rise of saline groundwater will transport salts to the soil surface. At the surface, water evaporates, leaving the salts behind. If this process is not arrested, salt accumulation will continue, resulting in salinization of the soil. In such cases, sub-surface drainage can control the rise of the water table and hence prevent salinization.

STRATEGIES FOR MANAGING TREATED WASTEWATER ON THE FARM

To overcome salinity hazards
To overcome toxicity hazards
To prevent health hazards

Success in using treated wastewater for crop production will largely depend on adopting appropriate strategies aimed at optimizing crop yields and quality, maintaining soil productivity and safeguarding the environment. Several alternatives are available and a combination of these alternatives will offer an optimum solution for a given set of conditions. The user should have prior information on effluent supply and its quality, as indicated in Table F-3, to ensure the formulation and adoption of an appropriate on-farm management strategy.

The components of an on-farm strategy in using treated wastewater will consist of a combination of:

- Crop selection,
- selection of irrigation method, and
- adoption of appropriate management practices.

Furthermore, when the farmer has additional sources of water supply, such as a limited amount of normal irrigation water, he will then have an option to use both the effluent and the conventional source of water in two ways, namely:

- By blending conventional water with treated effluent, and
- using the two sources in rotation.

These are discussed briefly in the following sections.

Table F-3: INFORMATION REQUIRED ON EFFLUENT SUPPLY AND QUALITY

Information	Decision on irrigation management
Effluent supply	
The total amount of effluent that would be made available during the crop growing season.	Total area that could be irrigated.
Effluent available throughout the year.	Storage facility during non-crop growing period either at the farm or near wastewater treatment plant, and possible use for aquaculture.
The rate of delivery of effluent either as m^3 per day or litres per second.	Area that could be irrigated at any given time, layout of fields and facilities and system of irrigation.
Type of delivery: continuous or intermittent, or on demand.	Layout of fields and facilities, irrigation system, and irrigation scheduling.
Mode of supply: supply at farm gate or effluent available in a storage reservoir to be pumped by the f	The need to install pumps and pipes to transport effluent and irrigation system.

farmer.	
Effluent quality	
Total salt concentration and/or electrical conductivity of the effluent.	Selection of crops, irrigation method, leaching and other management practices.
Concentrations of cations, such as Ca^{++}, Mg^{++} and Na^{+}.	To assess sodium hazard and undertake appropriate measures.
Concentration of toxic ions, such as heavy metals, Boron and Cl^{-}.	To assess toxicities that are likely to be caused by these elements and take appropriate measures.
Concentration of trace elements (particularly those which are suspected of being phyto-toxic).	To assess trace toxicities and take appropriate measures.
Concentration of nutrients, particularly nitrate-N.	To adjust fertilizer levels, avoid over-fertilization and select crop.
Level of suspended sediments.	To select appropriate irrigation system and measures to prevent clogging problems.
Levels of intestinal nematodes and faecal coliforms.	To select appropriate crops and irrigation systems.

CROP SELECTION

To overcome salinity hazards

Not all plants respond to salinity in a similar manner; some crops can produce acceptable yields at much higher soil salinity than others. This is because some crops are better able to make the needed osmotic adjustments, enabling them to extract more water from a saline soil. The ability of a crop to adjust to salinity is extremely useful. In areas where a build-up of soil salinity cannot be controlled at an acceptable concentration for the crop being grown, an alternative crop can be selected that is both more tolerant of the expected soil salinity and able to produce economic yields. There is an 8-10 fold range in the salt tolerance of agricultural crops. This wide range in tolerance allows for greater use of moderately saline water, much of which was previously thought to be unusable. It also greatly expands the acceptable range of water salinity (ECw) considered suitable for irrigation.

The relative salt tolerance of most agricultural crops is known well enough to give general salt tolerance guidelines. Table F-4 presents a list of crops classified according to their tolerance and sensitivity to salinity. Figure F-1 presents the relationship between relative crop yield and irrigation water salinity with regard to the four crop salinity classes. The following general conclusions can be drawn from these data:

i. full yield potential should be achievable with nearly all crops when using a water with salinity less than 0.7 dS/m,

ii. When using irrigation water of slight to moderate salinity (i.e. 0.7-3.0 dS/m), full yield potential is still possible, but care must be taken to achieve the required leaching fraction in order to maintain soil salinity within the tolerance of the crops. Treated sewage effluent will normally fall within this group,

iii. For higher salinity water (more than 3.0 dS/m) and sensitive crops, increasing leaching to satisfy a leaching requirement greater than 0.25 to 0.30 might not be practicable because of the excessive amount of water required. In such a case, consideration must be given to changing to a more tolerant crop that will require less leaching, to control salts within crop tolerance levels. As water salinity (ECw) increases within the slight to moderate range, production of more sensitive crops may be restricted due to the inability to achieve the high leaching fraction needed, especially when grown on heavier, more clayey soil types.

Figure F-1: Divisions for relative salt tolerance ratings of agricultural crops (Maas 1984)

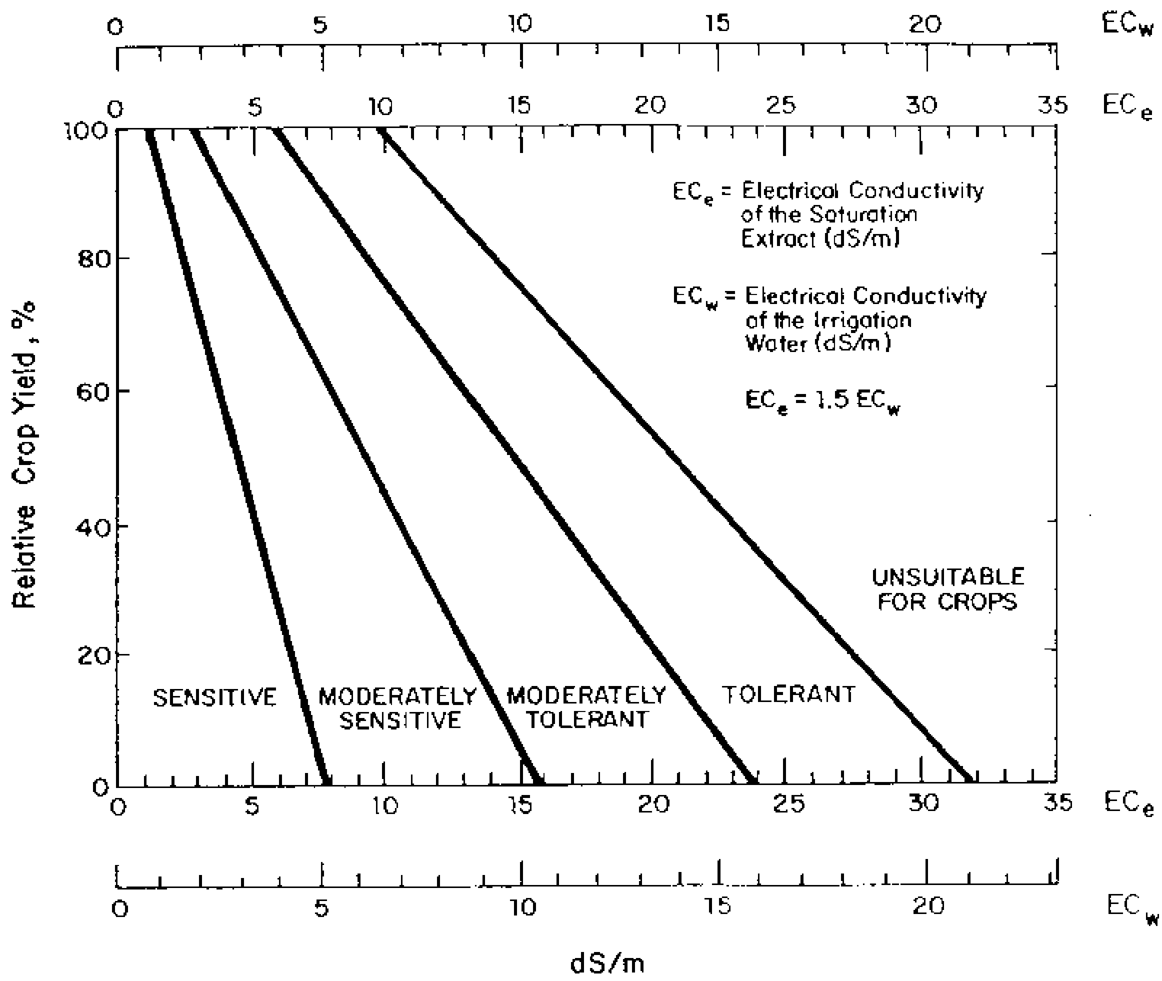


Table F-4: RELATIVE SALT TOLERANCE OF AGRICULTURAL CROPS

TOLERANT	
Fibre, Seed and Sugar Crops	
Barley	*Hordeum vulgare*
Cotton	*Gossypium hirsutum*
Jojoba	*Simmondsia chinensis*
Sugarbeet	*Beta vulgaris*
Grasses and Forage Crops	
Alkali grass	*Puccinellia airoides*
Alkali sacaton	*Sporobolus airoides*
Bermuda grass	*Cynodon dactylon*

Kallar grass	*Diplachne fusca*
Saltgrass, desert	*Distichlis stricta*
Wheatgrass, fairway crested	*Agropyron cristatum*
Wheatgrass, tall	*Agropyron elongatum*
Wildrye, Altai	*Elymus angustus*
Wildrye, Russian	*Elymus junceus*
Vegetable Crops	
Asparagus	*Asparagus officinalis*
Fruit and Nut Crops	
Date palm	*Phoenix dactylifera*
MODERATELY TOLERANT	
Fibre, Seed and Sugar Crops	
Cowpea	*Vigna unguiculata*
Oats	*Avena sativa*
Rye	*Secale cereale*
Safflower	*Carthamus tinctorius*
Sorghum	*Sorghum bicolor*
Soybean	*Glycine max*
Triticale	*X Triticosecale*
Wheat	*Triticum aestivum*
Wheat, Durum	*Triticum turgidum*
Grasses and Forage Crops	
Barley (forage)	*Hordeum vulgare*
Brome, mountain	*Bromus marginatus*
Canary grass, reed	*Phalaris, arundinacea*
Clover, Hubam	*Melilotus alba*
Clover, sweet	*Melilotus*

Fescue, meadow	*Festuca pratensis*
Fescue, tall	*Festuca elatior*
Harding grass	*Phalaris tuberosa*
Panic grass, blue	*Panicum antidotale*
Rape	*Brassica napus*
Rescue grass	*Bromus unioloides*
Rhodes grass	*Chloris gayana*
Grasses and Forage Crops	
Ryegrass, Italian	*Lolium italicum multiflorum*
Ryegrass, perennial	*Lolium perenne*
Sudan grass	*Sorghum sudanense*
Trefoil, narrowleaf birdsfoot	*Lotus corniculatus tenuifolium*
Trefoil, broadleaf	*L. corniculatus arvenis*
Wheat (forage)	*Triticum aestivum*
Wheatgrass, standard crested	*Agropyron sibiricum*
Wheatgrass, intermediate	*Agropyron intermedium*
Wheatgrass, slender	*Agropyron trachycaulum*
Wheatgrass, western	*Agropyron smithii*
Wildrye, beardless	*Elymus triticoides*
Wildrye, Canadian	*Elymus canadensis*
Vegetable Crops	
Artichoke	*Helianthus tuberosus*
Beet, red	*Beta vulgaris*
Squash, zucchini	*Cucurbita pepo melopepo*
Fruit and Nut Crops	
Fig	*Ficus carica*
Jujube	*Ziziphys jujuba*

Olive	*Olea europaea*
Papaya	*Carica papaya*
Pineapple	*Ananas comosus*
Pomegranate	*Punica granatum*
MODERATELY SENSITIVE	
<u>Fibre, Seed and Sugar Crops</u>	
Broadbean	*Vicia faba*
Castorbean	*Ricinus communis*
Maize	*Zea mays*
Flax	*Linum usitatissimum*
Millet, foxtail	*Setaria italica*
Groundnut/peanut	*Arachis hypogaea*
Rice, paddy	*Oryza sativa*
Sugarcane	*Saccarum officinarum*
Sunflower	*Helianthus annuus palustris*
<u>Grasses and Forage Crops</u>	
Alfalfa	*Medicago sativa*
Bentgrass	*Agrostisstoloniferapalustris*
Bluestem, Angleton	*Dichanthium aristatum*
Brome, smooth	*Bromus inermis*
Buffelgrass	*Cenchrus ciliaris*
Burnet	*Poterium sanguisorba*
Clover, alsike	*Trifolium hydridum*
<u>Grasses and Forage Crops</u>	
Clover, Berseem	*Trifolium alexandrinum*
Clover, ladino	*Trifolium repens*
Clover, red	*Trifolium pratense*

Clover, strawberry	*Trifolium fragiferum*
Clover, white Dutch	*Trifolium repens*
Corn (forage) (maize)	*Zea mays*
Cowpea (forage)	*Vigna unguiculata*
Dallis grass	*Paspalum dilatatum*
Foxtail, meadow	*Alopecurus pratensis*
Grama, vlue	*Bouteloua gracilis*
Lovegrass	*Eragrostis sp.*
Milkvetch, Cicer	*Astragalus deer*
Oatgrass, tall	*Arrhenatherum, Danthonia*
Oats (forage)	*Avena saliva*
Orchard grass	*Dactylis glomerata*
Rye (forage)	*Secale cereale*
Sesbania	*Sesbania exaltata*
Siratro	*Macroptilium atropurpureum*
Sphaerophysa	*Spaerophysa salsula*
Timothy	*Phleum pratense*
Vetch, common	*Vicia angustifolia*
Vegetable Crops	
Broccoli	*Brassica oleracea botrytis*
Brussel sprouts	*B. oleracea gemmifera*
Cabbage	*B. oleracea capitata*
Cauliflower	*B. oleracea botrytis*
Celery	*Apium graveolens*
Corn, sweet	*Zea mays*
Cucumber	*Cucumis sativus*
Eggplant	*Solanum melongena esculentum*

Kale	*Brassica oleracea acephala*
Kohlrabi	*B. oleracea gongylode*
Lettuce	*Latuca sativa*
Muskmelon	*Cucumis melon*
Pepper	*Capsicum annum*
Potato	*Solanum tuberosum*
Pumpkin	*Cucurbita peop pepo*
Radish	*Raphanus sativus*
Spinach	*Spinacia oleracea*
Squash, scallop	*C. pepo melopepo*
Sweet potato	*Ipomoea batatas*
Tomato	*Lycopersicon lycopersicum*
Turnip	*Brassica rapa*
Watermelon	*Citrullus lanatus*
Fruit and Nut Crops	
Grape	*Vitis sp.*
SENSITIVE	
Fibre, Seed and Sugar Crops	
Bean	*Phaseolus vulgaris*
Guayule	*Parthenium argentatum*
Sesame	*Sesamum indicum*
Vegetable Crops	
Bean	*Phaseolus vulgaris*
Carrot	*Daucus carota*
Okra	*Abelmoschus esculentus*
Onion	*Allium cepa*
Parsnip	*Pastinaca sativa*

Fruit and Nut Crops	
Almond	*Prunus dulcis*
Apple	*Malus sylvestris*
Apricot	*Prunus armeniaca*
Avocado	*Persea americana*
Blackberry	*Rubus sp.*
Boysenberry	*Rubus ursinus*
Cherimoya	*Annona cherimola*
Cherry, sweet	*Prunus avium*
Cherry, sand	*Prunus besseyi*
Currant	*Ribes sp.*
Gooseberry	*Ribes sp.*
Grapefruit	*Citrus paradisi*
Lemon	*Citrus limon*
Lime	*Citrus aurantifolia*
Loquat	*Eriobotrya japonica*
Mango	*Mangifera indica*
Orange	*Citrus sinensis*
Passion fruit	*Passiflora edulis*
Peach	*Prunus persica*
Pear	*Pyrus communis*
Persimmon	*Diospyros virginiana*
Plum: Prune	*Prunus domestica*
Pummelo	*Citrus maxima*
Raspberry	*Rubus idaeus*
Rose apple	*Syzgium jambos*
Sapote, white	*Casimiroa edulis*

Strawberry	*Fragaria sp.*
Tangerine	*Citrus reticulata*

Source: FAO (1985)

iv. if the salinity of the applied water exceeds 3.0 dS/m, the water might still be usable but its use may need to be restricted to more permeable soils and more salt-tolerant crops, where high leaching fractions are more easily achieved. This is being practiced on a large scale in the Arabian Gulf States, where drip irrigation systems are widely used.

If the exact cropping patterns or rotations are not known for a new area, the leaching requirement must be based on the least tolerant of the crops adapted to the area. In those instances, where soil salinity cannot be maintained within acceptable limits of preferred sensitive crops, changing to more tolerant crops will raise the area's production potential. If there is any doubt about the effect of wastewater salinity on crop production, a pilot study should be undertaken to demonstrate the feasibility of irrigation and the outlook for economic success.

To overcome toxicity hazards

A toxicity problem is different from a salinity problem in that it occurs within the plant itself and is not caused by water shortage. Toxicity normally results when certain ions are taken up by plants with the soil water and accumulate in the leaves during water transpiration to such an extent that the plant is damaged. The degree of damage depends upon time, concentration of toxic material, crop sensitivity, and crop water use and, if damage is severe enough, crop yield is reduced. Common toxic ions in irrigation water are chloride, sodium, and boron, all of which will be contained in sewage. Each can cause damage individually or in combination. Not all crops are equally sensitive to these toxic ions. Some guidance on the sensitivity of crops to sodium, chloride, and boron are given in Tables F-5, F-6, and F-7, respectively. However, toxicity symptoms can appear in almost any crop if concentrations of toxic materials are sufficiently high. Toxicity often accompanies or complicates a salinity or infiltration problem, although it may appear even when salinity is not a problem.

The toxic ions of sodium and chloride can also be absorbed directly into the plant through the leaves when moistened during sprinkler irrigation. This typically occurs during periods of high temperature and low humidity. Leaf absorption speeds up the rate of accumulation of a toxic ion and may be a primary source of the toxicity.

In addition to sodium, chloride, and boron, many trace elements are toxic to plants at low concentrations, as indicated in Table 10 in Chapter 2. Fortunately, most irrigation supplies and sewage effluents contain very low concentrations of these trace elements and are generally not a problem.

However, urban wastewater may contain heavy metals at concentrations which will give rise to elevated levels in the soil and cause undesirable accumulations in plant tissue and crop growth reductions. Heavy metals are readily fixed and accumulate in soils with repeated irrigation by such wastewaters and may render them either non-productive or the product unusable. Surveys of wastewater use have shown that more than 85 % of the applied heavy metals are likely to accumulate in the soil, most at the surface. The levels at which heavy metals accumulation in the soil is likely to have a deleterious effect on crops are discussed in Chapter 5. Any wastewater use project should include monitoring of soil and plants for toxic materials.

To prevent health hazards

From the point of view of human consumption and potential health hazards, crops and cultivated plants may be classified into the following groups:

Table F-4: RELATIVE TOLERANCE OF SELECTED CROPS TO EXCHANGEABLE SODIUM

Sensitive	**Semi-tolerant**	**Tolerant**
Avocado	Carrot	Alfalfa
(Persea americana)	*(Daucus carota)*	*(Medicago sativa)*
Deciduous Fruits	Clover, Ladino	Barley
Nuts	*(Trifolium repens)*	*(Hordeum vulgare)*
Bean, green	Dallisgrass	Beet, garden
(Phaseolus vulgaris)	*(Paspalum dilatatum)*	*(Beta vulgaris)*
Cotton (at germination)	Fescue, tall	Beet, sugar
(Gossypium hirsutum)	*(Festuca arundinacea)*	*(Beta vulgaris)*
Maize	Lettuce	Bermuda grass
(Zea mays)	*(Lactuca sativa)*	*(Cynodon dactylon)*
Peas	Bajara	Cotton
(Pisum sativum)	*(Pennisetum typhoides)*	*(Gossypium hirsutum)*
Grapefruit	Sugarcane	Paragrass
(Citrus paradisi)	*(Saccharum officinarum)*	*(Brachiaria mutica)*
Orange	Berseem	Rhodes grass
(Citrus sinensis)	*(Trifolium alexandrinum)*	*(Chloris gayana)*

Peach	Benji	Wheatgrass, crested
(Prunus persica)	*(Mililotus parviflora)*	*(Agropyron cristatum)*
Tangerine	Raya	Wheatgrass, fairway
(Citrus reticulata)	*(Brassica juncea)*	*(agropyron cristatum)*
Mung	Oat	Wheatgrass, tall
(Phaseolus aurus)	*(Avena sativa)*	*(Agropyron elongatum)*
Mash	Onion	Karnal grass
(Phaseolus mungo)	*(Allium cepa)*	*(Diplachna fusca)*
Lentil	Radish	
(Lens culinaris)	*(Raphanus sativus)*	
Groundnut (peanut)	Rice	
(Arachis hypogaea)	*(Oryza sativus)*	
Gram	Rye	
(Cicer arietinum)	*(Secale cereale)*	
Cowpeas	Ryegrass, Italian	
(Vigna sinensis)	*(Lolium multiflorum)*	
	Sorghum	
	(Sorghum vulgare)	
	Spinach	
	(Spinacia oleracea)	
	Tomato	
	(Lycopersicon esculentum)	
	Vetch	
	(Vicia sativa)	
	Wheat	
	(Triticum vulgare)	

Source: Adapted from data of FAO-Unesco (1973); Pearson (1960); and Abrol (1982).

i. Food crops

- those eaten uncooked
- those eaten after cooking

ii. Forage and feed crops

- Direct access by animals
- those fed to animals after harvesting

Table F-5: CHLORIDE TOLERANCE OF SOME FRUIT CROP CULTIVARS AND ROOTSTOCKS

Crop	**Rootstock or Cultivar**	**Maximum permissible Cl^- without leaf injury[1]**	
		Root zone (Cl_e) (me/l)	**Irrigation water (Cl_w)[2 3] (me/l)**
	Rootstocks		
Avocado *(Persea americana)*	West Indian	7.5	5.0
	Guatemalan	6.0	4.0
	Mexican	5.0	3.3
Citrus *(Citrus spp.)*	Sunki Mandarin	25.0	16.6
	Grapefruit		
	Cleopatra mandarin		
	Rangpur lime		
	Sampson tangelo	15.0	10.0
	Rough lemon		
	Sour orange		
	Ponkan mandarin		
	Citrumelo 4475	10.0	6.7
	Trifoliate orange		
	Cuban shaddock		
	Calamondin		
	Sweet orange		
	Savage citrange		

	Rusk citrange		
	Troyer citrange		
Grape*(Vitis spp.)*	Salt Creek, 1613-3	40.0	27.0
	Dog Ridge	30.0	20.0
Stone Fruits *(Prunus spp.)*	Marianna	25.0	17.0
	Lovell, Shalil	10.0	6.7
	Yunnan	7.5	5.0
	Cultivars		
Berries *(Rubus spp.)*	Boysenberry	10.0	6.7
	Olallie clackberry	10.0	6.7
	Indian SUmmer	5.0	3.3
	Raspberry		
Grape*(Vitis spp.)*	Thompson seedless	20.0	13.3
	Perlette	20.0	13.3
	Cardinal	10.0	6.7
	Black Rose	10.0	6.7
Strawberry *(Fragaria spp.)*	Lassen	7.5	5.0
	Shasta	5.0	3.3

[1] For some crops, the concentration given may exceed the overall salinity tolerance of that crop and cause some reduction in yield in addition to that caused by chloride ion toxicities.

[2] Values given are for the maximum concentration in the irrigation water. The values were derived from saturation extract data (EC_e) assuming a 15-20 percent leaching fraction and EC_d = 1.5 EC_w.

[3] The maximum permissible values apply only to surface irrigated crops. Sprinkler irrigation may cause excessive leaf bum at values far below these.

Source: Adapted from Maas (1984).

Table F-6: RELATIVE BORON TOLERANCE OF AGRICULTURAL CROPS[1]

VERY SENSITIVE (<0.5 mg/l)	
Lemon	*Citrus limon*
Blackberry	*Rubus spp.*
SENSITIVE (0.5-0.75 mg/l)	
Avocado	*Persea americana*
Grapefruit	*Citrus X paradisi*
Orange	*Citrus sinensis*
Apricot	*Prunus armeniaca*
Peach	*Prunus persica*
Cherry	*Prunus avium*
Plum	*Prunus domestica*
Persimmon	*Diospyros kaki*
Fig, kadota	*Ficus carica*
Grape	*Vitis vinifera*
Walnut	*Juglans regia*
Pecan	*Carya illinoiensis*
Cowpea	*Vigna unguiculata*
Onion	*Allium cepa*
SENSITIVE (0.75-1.0 mg/l)	
Garlic	*Allium sativum*
Sweet potato	*Ipomoea batatas*
Wheat	*Triticum eastivum*
Barley	*Hordeum vulgare*
Sunflower	*Helianthus annuus*
Bean, mung	*Vigna radiata*
Sesame	*Sesamum indicum*

Lupine	*Lupinus hartwegii*
Strawberry	*Fragaria spp.*
Artichoke, Jerusalem	*Helianthus tuberosus*
Bean, kidney	*Phaseolus vulgaris*
Bean, lima	*Phaseolus lunatus*
Groundnut/Peanut	*Arachis hypogaea*
MODERATELY SENSITIVE (1.0-2.0 mg/l)	
Pepper, red	*Capsicum annuum*
Pea	*Pisum sativa*
Carrot	*Daucus carota*
Radish	*Raphanus sativus*
Potato	*Solanum tuberosum*
Cucumber	*Cucumis sativus*
MODERATELY TOLERANT (2.0-4.0 mg/l)	
Lettuce	*Lactuca sativa*
Cabbage	*B. oleracea capitata*
Celery	*Apium graveolens*
Turnip	*Brassica rapa*
Bluegrass, Kentucky	*Poa pratensis*
Oats	*Avena sativa*
Maize	*Zea mays*
Artichoke	*Cynara scolymus*
Tobacco	*Nicotiana tabacum*
Mustard	*Brassica juncea*
Clover, sweet	*Melilotus indica*
Squash	*Cucurbita pepo*
Muskmelon	*Cucumis melo*

TOLERANT (4.0-6.0 mg/l)	
Sorghum	*Sorghum bicolor*
Tomato	*L. lycopersicum*
Alfalfa	*Medicago sativa*
Vetch, purple	*Vicia benghalensis*
Parsley	*Petroselinum crispum*
Beet, red	*Beta vulgaris*
Sugarbeet	*Beta vulgaris*
VERY TOLERANT (6.0-15.0 mg/l)	
Cotton	*Gossypium hirsutum*
Asparagus	*Asparagus officinalis*

[1] Maximum concentrations tolerated in soil water without yield or vegetative growth reductions. Boron tolerances vary depending upon climate, soil conditions and crop varieties. Maximum concentrations in the irrigation water are approximately equal to these values or slightly less.

Source: Maas (1984)

iii. Landscaping plants:

- Unprotected areas with public access
- semi-protected areas

iv. Afforestation plants:

- commercial (fruit, timber, fuel and charcoal)
- environmental protection (including sand stabilization)

In terms of health hazards, treated effluent with a high microbiological quality is necessary for the irrigation of certain crops, especially vegetable crops eaten raw, but a lower quality is acceptable for other selected crops, where there is no exposure to the public (see Table 8 in Chapter 2). The WHO (1989) Technical Report No. 778 suggested a categorization of crops according to the exposed group and the degree to which health protection measures are required, as shown in Example 4.

EXAMPLE 4 - CATEGORIZATION OF CROPS IN RELATION TO EXPOSED GROUP AND HEALTH CONTROL MEASURES

Category A:

- Protection required for consumers, agricultural workers, and the general public,

- Includes crops likely to be eaten uncooked, spray-irrigated fruits and grass (sports fields, public parks and lawns);

Category B:

- Protection required for agricultural workers only,

- Includes cereal crops, industrial crops (such as cotton and sisal), food crops for canning, fodder crops, pasture and trees,

- In certain circumstances some vegetable crops might be considered as belonging to Category B if they are not eaten raw (potatoes, for instance) or if they grow well above ground (for example, chillies), in such cases it is necessary to ensure that the crop is not contaminated by sprinkler irrigation or by falling on to the ground, and that contamination of kitchens by such crops, before cooking, does not give rise to a health risk.

SELECTION OF IRRIGATION METHODS

The different types of irrigation methods have been introduced earlier. Under normal conditions, the type of irrigation method selected will depend on water supply conditions, climate, soil, crops to be grown, cost of irrigation method and the ability of the farmer to manage the system. However, when using wastewater as the source of irrigation other factors, such as contamination of plants and harvested product, farm workers, and the environment, and salinity and toxicity hazards, will need to be considered. There is considerable scope for reducing the undesirable effects of wastewater use in irrigation through selection of appropriate irrigation methods.

The choice of irrigation method in using wastewater is governed by the following technical factors:

- the choice of crops,
- the wetting of foliage, fruits and aerial parts,
- the distribution of water, salts and contaminants in the soil,
- the ease with which high soil water potential could be maintained,
- the efficiency of application, and
- the potential to contaminate farm workers and the environment.

Table F-7 presents an analysis of these factors in relation to four widely practiced irrigation methods, namely border, furrow, sprinkler, and drip irrigation.

Table F-7: EVALUATION OF COMMON IRRIGATION METHODS IN RELATION TO THE USE OF TREATED WASTEWATER

Parameters of evaluation	Furrow irrigation	Border irrigation	Sprinkler irrigation	Drip irrigation
1 Foliar wetting and consequent leaf damage resulting in poor yield	No foliar injury as the crop is planted on the ridge	Some bottom leaves may be affected but the damage is not so serious as to reduce yield	Severe leaf damage can occur resulting in significant yield loss	No foliar injury occurs under this method of irrigation
2 Salt accumulation in the root zone with repeated applications	Salts tend to accumulate in the ridge which could harm the crop	Salts move vertically downwards and are not likely to accumulate in the root zone	Salt movement is downwards and root zone is not likely to accumulate salts	Salt movement is radial along the direction of water movement. A salt wedge is formed between drip points
3 Ability to maintain high soil water potential	Plants may be subject to stress between irrigations	Plants may be subject . to water stress between irrigations	Not possible to maintain high soil water potential throughout the growing season	Possible to maintain high soil water potential throughout the growing season and minimize the effect of salinity
4 Suitability to handle brackish wastewater without significant yield loss	Fair to medium. With good management and drainage acceptable yields are possible	Fair to medium. Good irrigation and drainage practices can produce acceptable levels of yield	Poor to fair. Most crops suffer from leaf damage and yield is low	Excellent to good. Almost all crops can be grown with very little reduction in yield

Source: Kandiah (1990b)

A border (and basin or any flood irrigation) system involves complete coverage of the soil surface with treated effluent and is normally not an efficient method of irrigation. This system will also contaminate vegetable crops growing near the ground and root crops and will expose farm workers to the effluent more than any other method. Thus, from both the health and water conservation points of view, border irrigation with wastewater is not satisfactory.

Furrow irrigation, on the other hand, does not wet the entire soil surface. This method can reduce crop contamination, since plants are grown on the ridges, but complete health protection cannot be guaranteed. Contamination of farm workers is potentially medium to high, depending on automation. If the effluent is transported through pipes and delivered into individual furrows by means of gated pipes, risk to irrigation workers will be minimum.

The efficiency of surface irrigation methods in general, borders, basins, and furrows, is not greatly affected by water quality, although the health risk inherent in these systems is most certainly of concern. Some problems might arise if the effluent contains large quantities of suspended solids and these settle out and restrict flow in transporting channels, gates, pipes and appurtenances. The use of primary treated sewage will overcome many of such problems. To avoid surface ponding of stagnant effluent, land levelling should be carried out carefully and appropriate land gradients should be provided.

Sprinkler, or spray, irrigation methods are generally more efficient in terms of water use since greater uniformity of application can be achieved. However, these overhead irrigation methods may contaminate ground crops, fruit trees, and farm workers. In addition, pathogens contained in aerosolized effluent may be transported downwind and create a health risk to nearby residents. Generally, mechanized or automated systems have relatively high capital costs and low labour costs compared with manually-moved sprinkler systems. Rough land levelling is necessary for sprinkler systems, to prevent excessive head losses and achieve uniformity of wetting. Sprinkler systems are more affected by water quality than surface irrigation systems, primarily as a result of the clogging of orifices in sprinkler heads, potential leaf burns and phytotoxicity when water is saline and contains excessive toxic elements, and sediment accumulation in pipes, valves and distribution systems. Secondary wastewater treatment has generally been found to produce an effluent suitable for distribution through sprinklers, provided that the effluent is not too saline. Further precautionary measures, such as treatment with granular filters or micro-strainers and enlargement of nozzle orifice diameters to not less than 5 mm, are often adopted.

Localized irrigation, particularly when the soil surface is covered with plastic sheeting or other mulch, uses effluent more efficiently, can often produce higher crop yields and certainly provides the greatest degree of health protection for farm workers and consumers. Trickle and drip irrigation systems are expensive, however, and require a high quality of effluent to prevent clogging of the emitters through which water is slowly released into the soil. Table F-8 presents water quality requirements to prevent clogging in localized irrigation systems. Solids in the effluent or biological growth at the emitters will create problems but gravel filtration of secondary treated effluent and regular flushing of lines have been found to be effective in preventing such problems in Cyprus (Papadopoulos and Stylianou 1988). Bubbler irrigation, a technique developed for the localized irrigation of tree crops avoids the need for small emitter orifices but careful setting is required for its successful application (Hillel 1987).

Table F-8: WATER QUALITY AND CLOGGING POTENTIAL IN DRIP IRRIGATION SYSTEMS

Potential Problem	Units	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
Physical				
Suspended Solids	mg/l	< 50	50- 100	> 100
Chemical				
pH		< 7.0	7.0 - 8.0	> 8.0
Dissolved Solids	mg/l	< 500	500-2000	> 2000
Manganese	mg/l	< 0.1	0.1 - 1.5	> 1.5
Iron	mg/l	< 0.1	0.1 - 1.5	> 1.5
Hydrogen Sulphide	mg/l	< 0.5	0.5 - 2.0	> 2.0
Biological	maximum			
Bacterial populations	number/ml	< 10000	10 000 - 50 000	> 50000

Source: Adapted from Nakayama (1982)

When compared with other systems, the main advantages of trickle irrigation seem to be:

i. increased crop growth and yield achieved by optimizing the water, nutrients and air regimes in the root zone,

ii. High irrigation efficiency - no canopy interception, wind drift or conveyance losses and minimal drainage losses,

iii. Minimal contact between farm workers and effluent,

iv. Low energy requirements - the trickle system requires a water pressure of only 100-300 k Pa (1-3 bar),

v. low labour requirements - the trickle system can easily be automated, even to allow combined irrigation and fertilization (sometimes terms fertigation).

Apart from the high capital costs of trickle irrigation systems, another limiting factor in their use is that they are only suited to the irrigation of row crops. Relocation of subsurface systems can be prohibitively expensive.

Clearly, the decision on irrigation system selection will be mainly a financial one but it is essential that the health risks associated with the different methods will be taken into account.

As pointed out in Section 2.1, the method of effluent application is one of the health control measures possible, along with crop selection, wastewater treatment, and human exposure control. Each measure will interact with the others and thus a decision on irrigation system selection will have an influence on wastewater treatment requirements, human exposure control and crop selection (for example, row crops are dictated by trickle irrigation). At the same time the irrigation techniques feasible will depend on crop selection and the choice of irrigation system might be limited if wastewater treatment has already been decided before effluent use is considered.

FIELD MANAGEMENT PRACTICES IN WASTEWATER IRRIGATION

Water management
Land and soil management
Crop management and cultural practices

Management of water, soil, crop, and operational procedures, including precautions to protect farm workers, play an important role in the successful use of sewage effluent for irrigation.

Water management

Most treated wastewaters are not very saline, salinity levels usually ranging between 500 and 200 mg/l (ECw = 0.7 to 3.0 dS/m). However, there may be instances where the salinity concentration exceeds the 2000 mg/l level. In any case, appropriate water management practices will have to be followed to prevent salinization, irrespective of whether the salt content in the wastewater is high or low. It is interesting to note that even the application of a non-saline wastewater, such as one containing 200 to 500 mg/l, when applied at a rate of 20,000 m3 per hectare, a fairly typical irrigation rate, will add between 2 and 5 tones of salt annually to the soil. If this is not flushed out of the root zone by leaching and removed from the soil by effective drainage, salinity problems can build up rapidly. Leaching and drainage are thus two important water management practices to avoid salinization of soils.

Leaching

The concept of leaching has already been discussed. The question that arises is how much water should be used for leaching, i.e. what is the leaching requirement? To estimate the leaching requirement, both the salinity of the irrigation water (ECw) and the crop tolerance to soil salinity (ECe) must be known. The necessary leaching requirement (LR) can be estimated from Figure 14 for general crop rotations reported by Ayers and Westcot (FAO 1985). A more exact estimate of the leaching requirement for a particular crop can be obtained using the following equation:

(14)

$$LR = \frac{EC_w}{5(EC_e - EC_w}$$

Where:

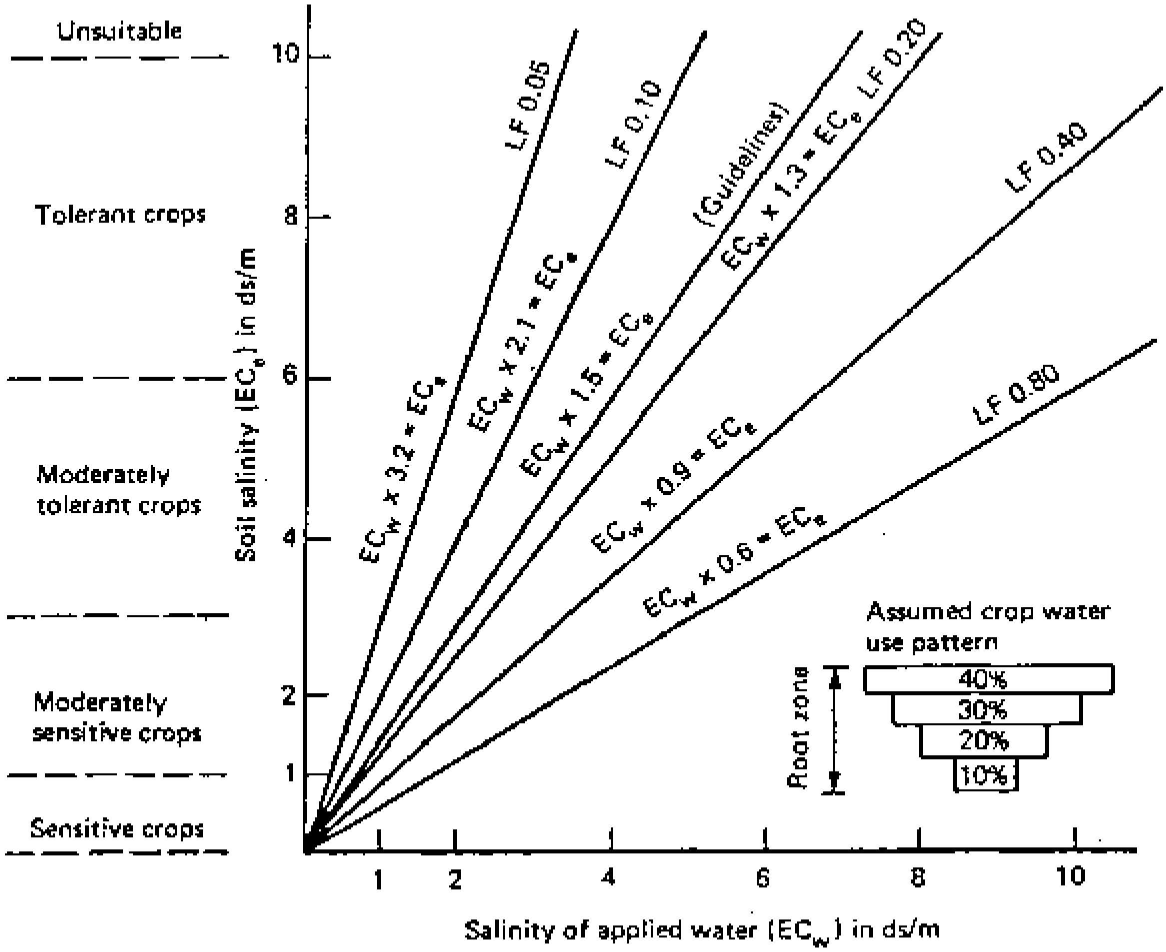
LR = minimum leaching requirement needed to control salts within the tolerance (EC_e) of the crop with ordinary surface methods of irrigation

EC_w = salinity of the applied irrigation water in dS/m

EC_e = average soil salinity tolerated by the crop as measured on a soil saturation extract. It is recommended that the EC_e value that can be expected to result in at least a 90% or greater yield be used in the calculation.

Figure F-2 was developed using ECe values for the 90% yield potential. For water in the moderate to high salinity range (>1.5 dS/m), it might be better to use the ECe value for maximum yield potential (100%) since salinity control is critical in obtaining good yields. Further information on this is contained in Irrigation and Drainage Paper 29, Rev. 1 (FAO 1985).

Figure F-2: Relationship between applied water salinity and soil water salinity at different leaching fractions (FAO 1985)



Where water is scarce and expensive, leaching practices should be designed to maximize crop production per unit volume of water applied, to meet both the consumptive use and leaching requirements. Depending on the salinity status, leaching can be carried out at each irrigation, each alternative irrigation or less frequently, such as seasonally or at even longer intervals, as necessary to keep the salinity in the soil below the threshold above which yield might be affected to an unacceptable level. With good quality irrigation water, the irrigation application level will usually apply sufficient extra water to accomplish leaching. With high salinity irrigation water, meeting the leaching requirement is difficult and requires large amounts of water. Rainfall must be considered in estimating the leaching requirement and in choosing the leaching method.

The following practices are suggested for increasing the efficiency of leaching and reducing the amount of water needed:

i. leach during cool seasons instead of during warm periods, to increase the efficiency and ease of leaching, since the total annual crop water demand (ET, mm/year) losses are lower,

ii. Use more salt-tolerant crops that require a lower leaching requirement (LR) and thus have a lower water demand,

iii. use tillage to slow overland water flow and reduce the number of surface cracks which bypass flow through large pores and decrease leaching efficiency,

iv. Use sprinkler irrigation at an application rate below the soil infiltration rate as this favours unsaturated flow, which is significantly more efficient for leaching than saturated flow. More irrigation time but less water is required than for continuous ponding,

v. use alternate ponding and drying instead of continuous ponding as this is more efficient for leaching and uses less water, although the time required to leach is greater. This may have drawbacks in areas having a high water table, which allows secondary salinization between pondings,

vi. Where possible, schedule leaching at periods of low crop water use or postpone leaching until after the cropping season,

vii. Avoid fallow periods, particularly during hot summers, when rapid secondary soil salinization from high water tables can occur,

viii. If infiltration rates are low, consider pre-planting irrigations or off-season leaching to avoid excessive water applications during the crop season, and

ix. Use one irrigation before the start of the rainy season if total rainfall is normally expected to be insufficient for a complete leaching. Rainfall is often the most efficient leaching method because it provides high quality water at relatively low rates of application.

Drainage

Salinity problems in many irrigation projects in arid and semi-arid areas are associated with the presence of a shallow water table. The role of drainage in this context is to lower the water table to a desirable level, at which it does not contribute to the transport of salts to the root zone and the soil surface by capillarity. What is important is to maintain a downward movement of water through soils. Van Schilfgaard (1984) reported that drainage criteria are frequently expressed in terms of critical water table depths; although this is a useful concept, prevention of salinization depends on the establishment, averaged over a period, of a downward flux of water. Another important element of the total drainage system is its ability to transport the desired amount of drained water out of the irrigation scheme and dispose of it safely. Such disposal can pose a serious problem, particularly when the source of irrigation water is treated wastewater, depending on the composition of the drainage effluent.

Timing of irrigation

The timing of irrigation, including irrigation frequency, pre-planting irrigation and irrigation prior to a winter rainy season can reduce the salinity hazard and avoid water stress between irrigations. Some of these practices are readily applicable to wastewater irrigation.

In terms of meeting the water needs of crops, increasing the frequency of irrigation will be desirable as it eliminates water stress between irrigations. However, from the point of view of overall water management, this may not always produce the desired results. For example, with border, basin and other flood irrigation methods, frequent irrigations may result in an unacceptable increase in the quantity of water applied, decrease in water use efficiency and larger amounts of water to be drained. However, with sprinklers and localized irrigation methods, frequent applications with smaller amounts may not result in decrease in water use efficiency and, indeed, could help to overcome the salinity problem associated with saline irrigation water.

Pre-planting irrigation is practised in many irrigation schemes for two reasons, namely: (i) to leach salts from the soil surface which may have accumulated during the previous cropping period and to provide a salt-free environment to germinating seeds (it should be noted that for most crops, the seed germination and seedling stages are most sensitive to salinity); and (ii) to provide adequate moisture to germinating seeds and young seedlings. A common practice among growers of lettuce, tomatoes, and other vegetable crops is to pre-irrigate the field before planting, since irrigation soon after planting could create local water stagnation and wet spots that are not desirable. Treated wastewater is a good source for pre-irrigation as it is normally not saline and the health hazards are practically nil.

Blending of wastewater with other water supplies

One of the options that may be available to farmers is the blending of treated sewage with conventional sources of water, canal water, or ground water, if multiple sources are available. It is possible that a farmer may have saline ground water and, if he has non-saline treated wastewater, could blend the two sources to obtain a blended water of acceptable salinity level. Further, by blending, the microbial quality of the resulting mixture could be superior to that of the unblended wastewater.

Alternating treated wastewater with other water sources

Another strategy is to use the treated wastewater alternately with the canal water or groundwater, instead of blending. From the point of view of salinity control, alternate applications of the two sources will be superior to blending. However, an alternating application strategy will require duel conveyance systems and availability of the effluent dictated by the alternate schedule of application.

Land and soil management

Several land and soil management practices can be adopted at the field level to overcome salinity, sodicity, toxicity, and health hazards that might be associated with the use of treated wastewater.

Land development

During the early stages of on-farm land development, steps can be taken to minimize potential hazards that may result from the use of wastewater. These will have to be well planned, designed and executed since they are expensive and, often, one time operations. Their goal is to improve permanently existing land and soil conditions in order to make irrigation with wastewater easier. Typical activities include levelling of land to a given grade, establishing adequate drainage (both open and sub-surface systems), deep ploughing and leaching to reduce soil salinity.

Land grading

Land grading is important to achieve good uniformity of application from surface irrigation methods and acceptable irrigation efficiencies in general. If the wastewater is saline, it is very important that the irrigated land be appropriately graded. Salts accumulate in the high spots that have too little water infiltration and leaching, while in the low spots water accumulates, causing water logging and soil crusting.

Land grading is well accepted as an important farm practice in irrigated agriculture. Several methods are available to grade land to a desired slope. The slope required will vary with the irrigation system, length of run of water flow, soil type, and the design of the field. Recently, laser techniques have been applied to level land precisely to obtain high irrigation efficiencies and prevent salinization.

Deep cultivation

In certain areas, the soil is stratified, and such soils are difficult to irrigate. Layers of clay, sand, or hardpan in stratified soils frequently impede or prevent free movement of water through and beyond the root zone. This will not only lead to saturation of the root zone but also to accumulation of salts in the root zone. Irrigation efficiency as well as water movement in the soil can be greatly enhanced by sub-soiling and chiselling of the land. The effects of sub-soiling and chiselling remain for about 1 to 5 years but, if long term effects are required, the land should be deep, and slip ploughed. Deep or slip ploughing is costly and usually requires the growing of annual crops soon after to allow the settling of the land. Following a couple of grain crops, grading will be required to re-establish a proper grade to the land.

Crop management and cultural practices

Several cultural and crop management practices that are valid under saline water use will be valid under wastewater use. These practices are aimed at preventing damage to crops caused by salt accumulation surrounding the plants and in the root zone and adjusting fertilizer and agrochemical applications to suit the quality of the wastewater and the crop.

Placement of seed

In most crops, seed germination is more seriously affected by soil salinity than other stages of development of a crop. The effects are pronounced in furrow-irrigated crops, where the water is fairly to highly saline. This is because water moves upwards by capillarity in the ridges, carrying salts with it. When water is either absorbed by roots or evaporated, salts are deposited in the ridges. Typically, the highest salt concentration occurs in the centre of the ridge, whereas the lowest concentration of salt is found along the shoulders of the ridges. An efficient means of overcoming this problem is to ensure that the soil around the germinating seeds is sufficiently low in salinity. Appropriate planting methods, ridge shapes, and irrigation management can significantly decrease damage to germinating seeds. Some specific practices include:

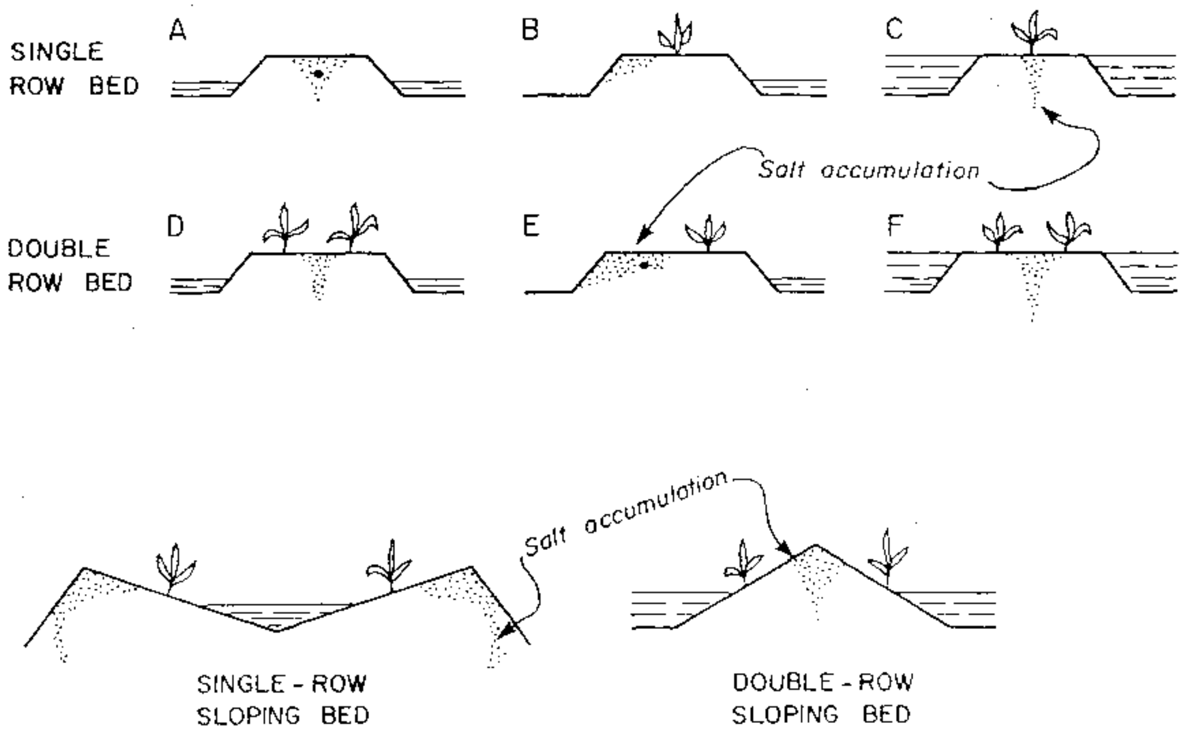
i. Planting on the shoulder of the ridge in the case of single row planting or on both shoulders in double row planting,

ii. Using sloping beds with seeds planted on the sloping side, but above the water line,

iii. Irrigating alternate rows so that the salts can be moved beyond the single seed row.

Figure F-3 presents schematic representations of salt accumulation, planting positions, ridge shapes and watering patterns.

Figure F-3: Schematic representations of salt accumulation and planting methods in ridge and furrow irrigation (Bernstein and Fireman 1957)



PLANNING FOR WASTEWATER IRRIGATION

Central planning

Desirable site characteristics

Crop selection issues

Central planning

Government policy on effluent use in agriculture will have a deciding effect on what control measures can be achieved through careful selection of site and crops to be irrigated with treated effluent. A decision to make treated effluent available to farmers for unrestricted irrigation or to irrigate public parks and urban green areas with effluent will remove the possibility of taking advantage of careful selection of sites, irrigation techniques, and crops in limiting the health risks and minimizing environmental impacts. However, if a Government decides that effluent irrigation will only be applied in specific controlled areas, even if crop selection is not limited (that is, unrestricted irrigation is allowed within these areas), public access to the irrigated areas will be prevented and some of the control measures described in Chapter 2 can be applied. Without doubt, the greatest security against health risk and adverse environmental impact will be achieved by limiting effluent use to restricted irrigation on controlled areas to which the public has no access but even imposing restrictions on effluent irrigation by farmers, if properly enforced, can achieve a degree of control.

Cobham and Johnson (1988) have suggested that the procedures involved in preparing plans for effluent irrigation schemes are similar to those used in most forms of resource planning and summarized the main physical, social, and economic dimensions as in Figure F-4. They also indicated that a number of key issues or tasks were likely to have a significant effect on the ultimate success of effluent irrigation, as follows:

i. organizational and managerial provisions made to administer the resource, to select the effluent use plan and to implement it,

ii. The importance attached to public health considerations and the levels of risk taken,

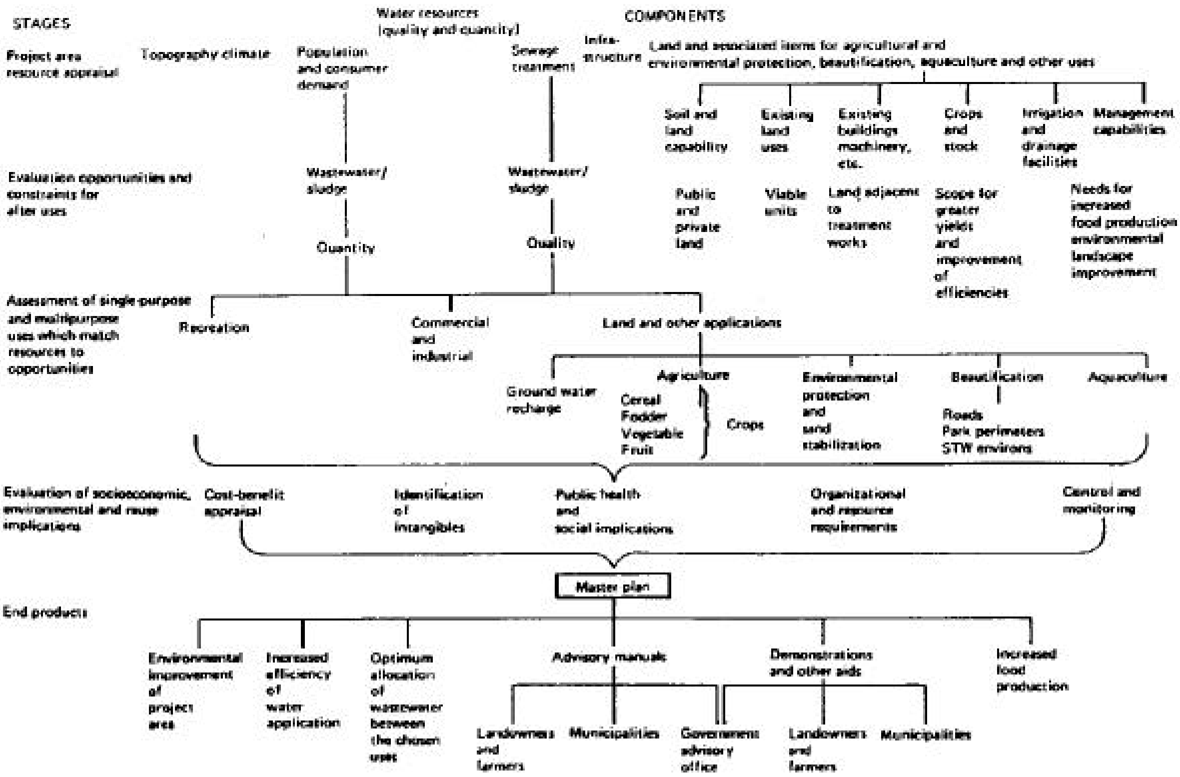
iii. The choice of single-use or multiple-use strategies,

iv. The criteria adopted in evaluating alternative reuse proposals,

v. The level of appreciation of the scope for establishing a forest resource.

Adopting a mix of effluent use strategies is normally advantageous in respect of allowing greater flexibility, increased financial security and more efficient use of the wastewater throughout the year, whereas a single-use strategy will give rise to seasonal surpluses of effluent for unproductive disposal. Therefore, in site and crop selection the desirability of providing areas for different crops and forestry so as to utilize the effluent at maximum efficiency over the whole yearly cycle of seasons must be kept in mind.

Figure F-4: Main components of general planning guidelines for wastewater reuse (Cobham and Johnson 1988)



Desirable site characteristics

The features which are critical in deciding the viability of a land disposal project are the location of available land and public attitudes. Land which is far distant from the sewage treatment plant will incur high costs for transporting treated effluent to site and will generally not be suitable. Hence, the availability of land for effluent irrigation should be considered when sewerage is being planned and sewage treatment plants should be strategically located in relation to suitable agricultural sites. Ideally, these sites should not be close to residential areas but even remote land might not be acceptable to the public if the social, cultural, or religious attitudes are opposed to the practice of wastewater irrigation. The potential health hazards associated with effluent irrigation can make this a very sensitive issue and public concern will only be mollified by the application of strict control measures. In arid areas, the importance of agricultural use of treated effluent makes it advisable to be as systematic as possible in planning, developing and managing effluent irrigation projects and the public must be kept informed at all stages.

The ideal objective in site selection is to find a suitable area where long-term application of treated effluent will be feasible without adverse environmental or public health impacts. It might be possible in a particular instance to identify several potential sites within reasonable distance of the sewered community and the problem will be to select the most suitable area or areas, considering all relevant factors. The following basic information on an area under consideration will be of value, if available:

- A topographic map,
- Agricultural soils surveys,
- Aerial photographs,
- Geological maps and reports,
- Groundwater reports and well logs,
- Boring logs and soil test results,
- Other soil and peizometric data.

At this preliminary stage of investigation, it should be possible to assess the potential impact of treated effluent application on any usable aquifer in the area(s) concerned. The first ranking of sites should take into account other factors, such as the cost and location of the land, its present use, and availability, and social factors, in addition to soil and groundwater conditions.

The characteristics of the soil profile underlying a particular site are very important in deciding on its suitability for effluent irrigation and the methods of application to be employed. Among the soil properties important from the point of view of wastewater, application and agricultural production are physical parameters (such as texture, grading, liquid, and plastic limits, etc.), permeability, water-holding capacity, pH, salinity, and chemical composition. Preliminary observation of sites, which could include shallow hand-auger borings and identification of vegetation, will often allow the elimination of clearly unsatisfactory sites. After elimination of marginal sites, each site under serious consideration must be investigated by on-site borings to ascertain the soil profile, soil characteristics, and location of the water table. Peizometers should be located in each borehole and these can be used for subsequent groundwater sampling. A procedure for such site assessment has been described by Hall and Thompson (1981) and, if applied, should not only allow the most suitable site among several possible to be selected but permit the impact of effluent irrigation at the chosen site to be modeled. When a site is developed, a long-term groundwater-monitoring programme should be an essential feature of its management.

Crop selection issues

Normally, in choosing crops, a farmer is influenced by economics, climate, soil and water characteristics, management skill, labour and equipment available and tradition. The degree to which the use of treated effluent influences crop selection will depend on Government policy on effluent irrigation, the goals of the user and the effluent quality. Government policy will have the objectives of minimizing the health risk and influencing the type of productivity associated with effluent irrigation. Regulations must be realistic and achievable in the context of national and local environmental conditions and traditions. At the same time, planners of effluent irrigation schemes must attempt to achieve maximum productivity and water conservation through the choice of crops and effluent application systems.

A multiple-use strategy approach will require the evaluation of viable combinations of the cropping options possible on the land available. This will entail a considerable amount of survey and resource budgeting work, in addition to the necessary soil and water quality assessments. The annual, monthly, and daily water demands of the crops, using the most appropriate irrigation techniques, have to be determined. Domestic consumption, local production, and imports of the various crops must be assessed so that the economic potential of effluent irrigation of the various crop combinations can be estimated. Finally, the crop irrigation demands must be matched with the available effluent to achieve optimum physical and financial utilization throughout the year. This process of assessment is reviewed by Cobham and Johnson (1988) for the case of effluent use in Kuwait, where afforestation for commercial purposes was found to offer significant potential in multiple-use effluent irrigation.

APPENDIX G
INCEPTION WORKSHOP \ PUBLIC INVOLVEMENT, MINUTES OF MEETING \ QUESTIONNAIRES

- **Official Invitation Letter:**

Attention: Name, Position

Project: Improved Environmental Practices and Policies – USAID
Solid Waste and Wastewater Management in the
Higher Chouf - Mount Lebanon

Subject: Invitation to Inception Workshop

Dear Mr. /Ms. Name,

The United States Agency for International Development (USAID) has recently launched its Improved Environmental Practices and Policies Programme aiming at improving waste management capabilities in rural areas in Lebanon.

USAID executes such programmes with the assistance of local partners. The Pontifical Mission with the technical support of ARD (environmental consultants), are assisting in the implementation of this programme in the Higher Chouf area, which covers 12 municipalities and a total population of up to 25,000 persons.

The project will include the construction of one solid waste treatment center and nine wastewater treatment plants and associated sewer networks. The construction activities are supported by a comprehensive training, awareness and public participation plan, which will contribute to the sustainability of the project by providing increased environmental awareness, improved technical capabilities, and enhanced coordination and partnership among the different project stakeholders.

These activities are initiated with the launching of an inception workshop. This workshop offers the opportunity to 1) promote coordination with the government, 2) promote coordination with project partners (such as farmers, recycling factories, local community) from the early stages of the project, 3) inform the local community about the project and 4) obtain comments and suggestions for improved results.

Your participation in the inception workshop would therefore be valuable to the overall sustainability and success of the project (see attached agenda).

Your confirmation is highly appreciated.

Thank you,

Issam Bishara
Regional Director – CNEWA/Pontifical Mission

- **Meeting Agenda**

9:30 - 10:00	**Registration**
10:00 - 10:30	**Introductory speeches** Union of Higher Chouf Municipalities, Mr. Hikmat Mallak CNEWA/Pontifical Mission, Mr. Rabih Seba United States Agency for International Development, Mrs. Sana Saliba
10:30 - 11:00	**Project presentation** Arab Resources Development (ARD), Dr. Walid Chahine
11:00- 12:00	**Questions & Answers**
12:00 – 12:30	**Brunch**

- **List of official invitees to the Inception Workshop on the 18th of October 2003**:

1. Table listing the Various ministries and their Coordinates:

Ministries\ official councils	*Director General*	*Coordinates\ Phones and Fax numbers*	*Version of invitation letter to be sent in*
Ministry of Environment (MoE)* (2 persons)	Dr. Berj Hatjian	Tel:04\522222 04\523593 Fax:04/525080	Arabic
Ministry of Interior and Municipalities(MoIM)	Mr. Attalah Ghacham	Tel:01\750083 Fax:01/340240	Arabic
Ministry of Energy and Water(MoEW)	Dr. Fady Comair	Tel:01\565100-1-2-3-4 Fax: 01/576666	Arabic
Ministry of Health(MoH)	Dr. Walid Aammar CC: to Dr. Farid Karam	Tel:01\615773-4-5-6 01/615724-5 Fax:01/615730	Arabic
Ministry of Public Work and Transport(MoPWT)	Eng. Fady Namar	Tel:05\456482 05\455821-2 Fax: 05/459660	Arabic
Ministry of Industry (MoI)	Eng. Fady Samaha	Tel:01\427046 01\427006 Fax:01/424677	Arabic
Ministry of Agriculture (MoA)	Eng. Louis Lahoud	Tel:01\200280-1 Fax:01/200280-1	Arabic
CDR Council of Development and Reconstruction	Dr. Jawdat Abou Jawdeh	Tel:01\980096-7 01\981431-4 Fax:01\981252-3	Arabic

* To invite two concerned personnel involved in Wastewater and Solid waste management

2. Table listing the various NGOs as USAID partners and environmental organizations:

USAID PARTNERS	***GENERAL DIRECTOR***	***COORDINATES\ PHONES AND FAX NUMBERS***	***VERSION OF INVITATION LETTER TO BE SENT IN***
World Vision			English
Ymca	Mr.Ghassan Saiyah	Tel\Fax:01\490640 Email:ymca@ymca-leb.org.lb	English
Mercy Corps		Tel:01\611586 Fax:01\611585 Email:mci@sodetel.net.lb	English
CHF		Tel:	English
SRI		Tel:	English
AFDC	Mr.Akram Chehaib Mr. Mounir Bou Ghanem	Tel: 01\752670 - 03\493281 Fax:05\280430 - 01\983917 Email:afdc@afdc.org.lb	Arabic\English
ARZ EL SHOUF	Mr. Nizar Hani	Tel:05\311230 - 03\628472 03\513854 Fax:05\311230	Arabic\ English

3. Table of Recycling Companies in Lebanon:

CATEGORY	COMPANY	CONTACT	LOCATION	TEL. NUMBER
Paper, cardboard	Solicar	Antoine Ghanem	Wadi Chahrour	01-940248/9
	Sipco	Mohammed Ghandour	Kfarchima	01-433500/53
	Sicomo	Jihad Azar	Kabb Elias	08-805039
	C.b.c	Laurent Chidiac	Jbeil	09-444023
	Ninex	George Abou Jaoude	Zouk Mosbeh	09-218400/1/2
Plastics	Hariri	Yehya Hariri	Saida	03-247790
	Rocky	Robert Khoury	-	03634400
	Lebanese recycling works	Elie Debs	Naher el Mot	01-888057 03-259065
Metals	Liban fonderies	Sami Nassar	Roumieh	03-703246
	Ugtal	Khaled Zouein	Taanayel-Bekaa	08-511747
	Tanak factory	-	Choueifat	08-432011

- **List of Attendance at the Workshop:**

Name	Company - Institution	Telephone	Fax	E-mail
Riyad Zein El-Dine	Mayor of Khraybeh	03-819467		
Mahmoud Slim	Mayor of Jbaa	03-827303		
Walid Abou Chakra	P.S.P. Aammatour	03-655534		
Elie ateif	Baadaran	03-451736		
Nabil el-Debis	P.S.P. Moukhtara	03-600545		
Marwan Zein el Dine	Butmeh	03-816302		
Ra'fat Baz	President of Baadaran Association			
Ghazi Issa	Cooperative Housing Foundation CHF	03-368092 01-853263		
Omar Kanaan	Secretary of Cultural and Social council for West-Bekaa and Rachaya	01-814123 01-790002/3	01-869011/26	omar.kanaan@dargroup.com
Chadia Abed El-Saed	Responsible of Women's Union (P.S.P.)	05-510335		
Jean Salemeh	YMCA	03-628284		
Kawkab Abed El-Samad	Responsible of Women's Right board in Aammatour	03-726316 05-311580		
Samir Abou Chakra	Mayor of Aammtour	03-707067	05-310441	
Mansour Zein el Dine	President of municipality of Butmeh	05-310610		
Mireille Akl	World Vision Lebanon	04-401980	04-401982	miray_akl@wvi.org
Izzat Saad el Dine	President of municipality of Jbaa	03-641441		
Racha Abou chakra	Scouts of Aammatour	03-894605		
Hiba Abed El-Samad	Scouts of Aammatour	03-757724		
Sayed Bou Zayab	Ministry of Industry	01-426607 03-431911	01-423809	
Sana Saliba	USAID	04-543600	04-544251	salibasg@state.gov

Sanaa' Halal	Represanting Jbaa	03-678604		
Wakiaa Al-Barasighi	La Cime School - Haret Jindel	03-710399		
Hsein Hani	President of municipality of Baadaran	03-341174		
Khalil Awdeh	Director of the public school in Bater	03-775652		
Zouheir el Hisin		03-513167		zouheirh@cdr.gov.lb
Mahmoud Abou Assi	Agriculture cooperation Maasser El-Chouf	03-352670		
Farouk Merhebi	Habitat	01-753209	01-753209	fmerhebi@inco.com.lb
Melhem Mezher	Mayor of Niha	03-899588		
Jalal Raydan	PSP	03-836881		
Mahmoud Abou Chakra	President of Municipality of Aammatour	03-750970		
Mansour Abou Chakra	Director of the Public School of Aammatour	03-362278		
Maamora Abou Chakra	COOP of Aammatour	03-200360	05-506288	
Sami Nassar	Liban Fonderies - Beyrouth	01-897619		
Rifaat Azzam	PSP	03-220048		
Randa Hamadeh	Ministry of Public Health	01-611174/5	01-615761	randa_ham@hotmail.com
Naji Haddad	Mayor	03-495527		
Nadim Noujaim	President of Municipality of Maasser El-Chouf	05-350380		
Amine Abdul Sanad	Inspection Central	03-898790		
Raed Abou Chakra	NGO: Nashiton min agil el bi'ah- Aammatour	03-695891		
Walid el Achkar	PSP	03-386985		
Nasib zein El-Dine	Liwa' Newspaper	03-208291		
Sobheh Al-Doubeisi	Vice president of Mristi municipality	03-674103		
Nabil Abdallah	Mercy Corps	03-236425		nabdallah@lb.mercycorps.org

Jihad Azar	Sicomo	08-500550	08-500809	
Wissam Abou Daher	Shouf Cedar Society	05-311230 03-505205	05-311230	wissam@shoufcedar.org
Nizar Hani	Shouf Cedar Society	03-513845	05-311230	nizar@shoufcedar.org
Wahib Ghaith	President of the municipality of Niha	03-702721		
Mohamad Abou Chakra	Member of Niha Municipality			
Nami Khattar	Head of municipality of Bater	03-885121		
Noura Khattar	Scouts of Bater	03-422541		
Georges Chakar	Association "Abnak Maasser El-Chouf"	03-630133		
Nidal El-Achkar	Technical school of agriculture of Baaklene	05-506910		
Samih Abdelsamad	Public School of Khreibeh	08-506592		
Hossam Bashnak		03-331904		
Elie Debs	Lebanese Recycling Works	03-659065	01-888057	eliodebs@hotmail.com lrw@post.com
Wajfi Abdessamad	Engineer	03-676377		waj_d@hotmail.com
Hadi Abou Chakra	Responsible of Youth and sports in P.S.P.	03-531295		hadi_abuchacra@hotmail.com

- **Minutes of Meeting:**

After the presentation of Dr. Walid Chahine where the intended program and detailed projects for the Higher Shouf Area were highlighted; many concerns were raised by the various attendees about the presented projects tackling the wastewater and solid waste management in the Higher Shouf area.

Some of the main issues that were presented and discussed:

1. ***Objectives of the inception workshop***
2. ***Solid waste and wastewater management in rural areas in Lebanon***
3. ***Project description***
4. ***The CNEWA/Pontifical Mission approach***
5. ***The Infrastructure***
6. ***The Knowledge***
7. ***The Financial sustainability***
8. ***Environmental Impact assessment***
9. ***The expected outputs***

ELARD confirmed that the issue of locating the parcels where each municipality intends to build the plants on is studied and a complete detailed EIA will be presented before any approval or implementation.

Some main concerns in higher Shouf area were presented by the head of Aammatour municipality who confirmed that many health threats to the villagers is due to the infiltration of raw sewage into various springs in the area, hence, the urgent need for sewage treatment.

Furthermore, the fact that the imminent Municipal Solid Waste Management contract termination with the private company Sukleen made the issue of solid waste treatment a problem to be solved urgently. Above all, he showed as example, that around 57 million Lebanese Pounds were due on the municipality of Aammatour for that same private company.

ELARD stressed as well that the Solid Waste Treatment Projects would reduce the high cost of solid waste management incurred on the various municipalities by private companies, and assuring that the success of the programs lay in the hands of the local community acceptance and commitments.

Finally, many of the attendees welcomed the projects and urged the concerned parties to start the implementation phases as soon as possible.

APPENDIX H
EMP COMPLIANCE FORMS AND OFFICIAL PUBLIC NOTICES

APPENDIX I
COST OF ENVIRONMENTAL MONITORING PROGRAM

Table I-1: MONTHLY COST OF PERFORMANCE MONITORING FOR THE EAAS SYSTEM DURING THE EARLY OPERATIONAL PHASE

Sampling Location	*Analytical Parameter*	*Early Operational Phase Sampling Frequency*[3]	*Cost per sample in L.L.*	*Cost/month in L.L.*
EAAS Influent	BOD_5	1/W	30,000.00	120,000.00
	Total Nitrogen	1/2W	181,000.00	362,000.00
	Ammonia-nitrogen	1/W	12,000.00	48,000.00
	Total solids	1/W	35,000.00	140,000.00
Final settlement tank effluent	BOD_5	1/W	30,000.00	120,000.00
	Total Suspended Solids	1/W	22,500.00	90,000.00
	pH	D		
	Total Nitrogen	1/2W	181,000.00	362,000.00
	Ammonia- nitrogen	1/2W	12,000.00	24,000.00
	Nitrates	1/2W	13,500.00	27,000.00
	Nitrites	1/2W	13,500.00	27,000.00
Post-chlorination	Total & Fecal coliforms	1/W	24,000.00	96,000.00
Sludge holding tank contents (if applicable)	Nitrates	1/W	13,500.00	54,000.00
	Ammonia- nitrogen	1/W	12,000.00	48,000.00
	Total solids	1/W	35,000.00	140,000.00
	Volatile solids	1/2W	22,500.00	45,000.00
Settled sludge in holding tank	Nitrates	1/W	13,500.00	54,000.00
	Ammonia	1/W	12,000.00	48,000.00
	Total solids[4]	1/W	35,000.00	140,000.00
	Volatile solids	1/2W	22,500.00	45,000.00
			subtotal/month	1,989,500.00

[3] D: daily, 1/W: once per week, 1/2W: once per two weeks, M: monthly, 1/2M: once per two months

[4] Sum of Total Suspended Solids and Total Dissolved Solids

Table I-2: MONTHLY COST OF PERFORMANCE MONITORING FOR THE EAAS SYSTEM DURING THE ADVANCED OPERATIONAL PHASE

Sampling Location	*Analytical Parameter*	*Advanced Operational Phase Sampling Frequency*[5]	*Cost per sample in L.L.*	*Cost/month in L.L.*
Plant Influent	Biochemical Oxygen Demand $_5$	1/2M	30,000.00	15,000.00
	Total Suspended Solids	1/2M	22,500.00	11,250.00
	Total Nitrogen[6]	1/2M	181,000.00	100,000.00
	Ammonia- nitrogen	1/2M	12,000.00	6,000.00
EAAS Influent	BOD_5	1/2W	30,000.00	60,000.00
	Total Nitrogen	M	181,000.00	181,000.00
	Ammonia-nitrogen	M	12,000.00	12,000.00
	Total solids	1/2W	35,000.00	70,000.00
Final settlement tank effluent	BOD_5	1/2W	30,000.00	60,000.00
	Total Suspended Solids	1/2W	22,500.00	90,000.00
	pH	D	8,000.00	
	Total Nitrogen	M	181,000.00	181,000.00
	Ammonia- nitrogen	M	12,000.00	12,000.00
	Nitrates	M	13,500.00	13,500.00
	Nitrites	M	13,500.00	13,500.00
Post-chlorination	Total & Fecal coliforms	1/2W	24,000.00	48,000.00
Sludge holding tank contents (if applicable)	Nitrates Ammonia- nitrogen	M M	13,500.00 12,000.00	13,500.00 12,000.00
	Total solids[7]	1/2W	35,000.00	70,000.00
	Volatile solids	M	22,500.00	22,500.00
Settled sludge in holding tank	Nitrates	M	13,500.00	13,500.00
	Ammonia	M	12,000.00	12,000.00
	Total solids	1/2W	35,000.00	70,000.00
	Volatile solids	M	22,500.00	22,500.00
			subtotal/month	1,109,250.00

[5] D: daily, 1/W: once per week, 1/2W: once per two weeks, M: monthly, 1/2M: once per two months
[6] Carbon, Hydrogen, Nitrogen and Sulfur are sampled together using Elemental Analyzer method
[7] Sum of Total Suspended Solids and Total Dissolved Solids

Table I-3: MONTHLY COST OF PERFORMANCE MONITORING FOR THE EAAS SYSTEM FOR MINIMAL SAMPLING

Sampling Location	*Analytical Parameter*	*Minimum sampling*[8]	*Cost per sample in L.L.*	*Cost/month in L.L.*
Plant Influent	Biochemical Oxygen Demand $_5$	1/3M	30,000.00	10,000.00
	Total Suspended Solids	1/3M	22,500.00	7,500.00
	Total Nitrogen[9]	1/3M	181,000.00	60,333.33
	Ammonia- nitrogen	1/3M	12,000.00	4,000.00
EAAS Influent	BOD_5	M	30,000.00	30,000.00
	Total Nitrogen	1/2M	181,000.00	90,500.00
	Ammonia-nitrogen	1/2M	12,000.00	6,000.00
	Total solids	M	35,000.00	35,000.00
Final settlement tank effluent	BOD_5	M	30,000.00	30,000.00
	Total Suspended Solids	M	22,500.00	22,500.00
	pH	D	8,000.00	
	Total Nitrogen	1/2M	181,000.00	90,500.00
	Ammonia- nitrogen	1/2M	12,000.00	6,000.00
	Nitrates	1/2M	13,500.00	6,750.00
	Nitrites	1/2M	13,500.00	6,750.00
Post-chlorination	Total & Fecal coliforms	M	24,000.00	24,000.00
Sludge holding tank contents (if applicable)	Nitrates	1/2M	13,500.00	6,750.00
	Ammonia- nitrogen	1/2M	12,000.00	6,000.00
	Total solids[10]	M	35,000.00	35,000.00
	Volatile solids	M	22,500.00	22,500.00
Settled sludge in holding tank	Nitrates	1/2M	13,500.00	6,750.00
	Ammonia	1/2M	12,000.00	6,000.00
	Total solids	M	35,000.00	35,000.00
	Volatile solids	M	22,500.00	22,500.00
			subtotal/month	570,333.33

[8] D: daily, 1/W: once per week, 1/2W: once per two weeks, M: monthly, 1/2M: once per two months, 1/3M once per three months

[9] Carbon, Hydrogen, Nitrogen and Sulfur are sampled together using Elemental Analyzer method

[10] Sum of Total Suspended Solids and Total Dissolved Solids

APPENDIX J
SAMPLE TENDER DOCUMENTS FOR A WWTP